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Visual Recognition of Chinese Characters by Adult Chinese Readers

by

Pui-wan CHENG

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Education

IN

Special Education

Department of Educational Psychology

EDMONTON, ALBERTA

Spring, 1986

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ISBN 0-315-30171-6

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Visual Recognition of Chinese Characters by Adult Chinese Readers submitted by Pui-wan CHENG in partial fulfilment of the requirements for the degree of Master of Education in Special Education.

R Mulcahy

Supervisor

Chi Kan Leung

Date April 14, 1986.

Abstract

The present study examined the performance of Chinese character recognition in 23 skilled and 23 less skilled adult Chinese readers via two experiments and a control task. The relationship between word recognition efficiency and reading comprehension ability is well established in the research literature of English. The purpose of the present investigation was to discover whether rapid, automatic recognition of context-free Chinese characters also bears an important relationship to comprehension ability in readers of Chinese.

Experiment 1 consisted of a vocalization task. In this experiment, the subjects were instructed to name a presented character as quickly and accurately as possible. Experiment 2 consisted of a lexical decision task. The subjects were asked to say "yes" to a real Chinese character and "no" to a pseudo Chinese character as quickly and accurately as possible. Matching dot patterns served as a control task in this study. The subjects were told to say "yes" to a matched pair of dot patterns and "no" to a nonmatched pair as rapidly and accurately as possible.

The results of both experiments showed that skilled readers were more accurate and more rapid in identifying Chinese characters, be they required to say the characters aloud or to make lexical judgements of the characters. These results, together with the no difference finding of matching dot patterns between skilled and less skilled readers, suggest that less skilled readers may be deficient in coding processes specific to verbal materials. The results of the present study therefore were in line with those revealed in the English language studies indicating an important relationship between word recognition efficiency and reading comprehension ability. The findings were discussed in terms of their practical applications, and in terms of possible dimensions for future research.

Acknowledgements

I would like to express my sincere appreciation to my advisor, Dr. R. Mulcahy, for his thoughtful guidance, inspiration, and support. A special debt of gratitude is extended to Dr. C. K. Leong, for the helpful advice, continued encouragement, and kind understanding he afforded me in the preparation of this thesis. I must also express my thanks to Dr. L. Wilgosh, for her editorial contributions and valuable suggestions. To Dr. A. E. Wall, I am grateful for his critical observations and constructive comments.

My final, and greatest debt is to members of the Cheng family, my husband, Wing-chung, my daughter, Xiang, and my son, Liang. Without their patience, support, and love, this piece of work could not have been completed.

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1. INTRODUCTION

> *The Chinese writing system is important and interesting for a number of reasons. It appears to be the only full and pure logography used in the modern world. It is used by a huge number of people; one billion Chinese speakers, who form one-quarter of the world population. Chinese characters are used also in Japan and Korea along with native phonetic scripts. The Chinese system is the medium through which a unique, ancient, and influential culture has flourished. It intrigues psychologists, educators, linguists, and computer scientists in the west because in appearance and use it contrasts sharply to Roman alphabets.*
>
> -- *Taylor & Taylor (1983, p.33)*

In an attempt to examine how differences among scripts may affect reading processes, research into different writing systems is gaining momentum in today's field of reading psychology (Kavanagh & Venezky, 1980; Tzeng & Singer, 1981). Much more work, however, has been done on reading in English than in any other languages. While there are controversies and issues remaining to be resolved, the bulk of research on English reading has revealed some general patterns on individual differences in reading ability (Stanovich, 1982a,b). One general pattern that the vast majority of reading psychologists agree on concerns the relationships between word recognition and reading ability. It has consistently been shown that there is a strong relationship between word recognition and reading comprehension ability in readers of English. In the belief that the more types of scripts we examine, the better the picture of the reading process we can draw, this study attempts to explore the word recognition and reading ability issue using the Chinese writing system. It is hoped that research into such a different script will shed new light on results from English.

Many current models of reading in English discuss reading ability in terms of the cognitive processes in reading (e.g. Laberge & Samuels, 1974; Perfetti & Lesgold, 1977; Rumelhart, 1977; Stanovich, 1980). The general account of reading processes includes components of lexical access (word recognition) and comprehension. Lexical processes usually refer to those lower-level cognitive processes that identify words, and comprehension processes are those higher-level processes that build meaning representations of the text. While results from a number of studies (e.g. Brown, Day, & Jones, 1983; Ryan, 1982) have shown that higher-level processing skills are sources of individual differences in reading fluency, there is much evidence indicating that cognitive processes operating at the lower-level are also significant contributors to variance in reading ability (Stanovich, 1982a,b).

On both theoretical and empirical grounds there is reason to support the proposition that word recognition is an important component of reading. First, nearly all models of the reading process include a subprocess of lexical access. More specifically, several models (e.g. Laberge & Samuels, 1974; Lesgold & Perfetti, 1977; Stanovich, 1980) clearly postulate a direct relationship between word identification skill and reading ability. Empirical research findings also give support to the strong correlation between word recognition skill and reading comprehension proficiency (e.g. Biemiller, 1977-78; Curtis, 1980; Perfetti & Hogaboam, 1975; Stanovich, 1981). Although this correlational relationship per se does not give power to a causal inference, the outcome of a longititudinal study (Lesgold & Resnick, 1982; Lesgold, Resnick, & Hammond, 1985) does suggest a causal relation between word recognition efficiency and reading comprehension ability.

In summary, the relationship between word recognition skill and reading ability is well estabilished, and most likely word recognition represents a causal factor in the development of reading proficiency. Reading theorists and researchers in this area, however, have generally confined their theories and experiments to English reading. Could similar relationships between word identification and reading ability be found in reading a logographic writing system, such as Chinese?

This study, therefore, is an attempt to determine the role of word recognition skill in reading Chinese. Of course more than word recognition is involved in reading and attempts to find a single factor on which all reading ability differences rest are surely misguided (Carr, 1981). However, if a relationship between word recognition skill and reading ability in Chinese readers can be demonstrated, some indication might be obtained as to the cognitive processes involved in reading Chinese. This in turn might give insight into the nature of reading as a universal cognitive activity (see Hung & Tzeng, 1981).

2. REVIEW OF RELATED LITERATURE

Since the present study deals with the reading behaviours of Chinese readers in an attempt to determine whether similar relationships between word recognition and reading comprehension exist in two different orthographies, Chinese and English, it is necessary to outline the relevant literature in these two writing systems thereby providing a theoretical framework for the study. The review of related literature will be presented in three parts. It begins with a review of theory and research in the reading of English with specification on the relationship between word identification and reading comprehension ability. Second, theoretical as well as empirical issues in the reading of Chinese will be discussed. The third section will summarize current and relevant research concerning the relationship between orthography and reading.

2.1 Theory and Research in Reading English

2.1.1 Current theories in reading English

During the past decade reading psychologists have attempted to conceptualize the reading process from the perspective of information processing. The basic framework of the information processing theory utilized in the study of psychology, according to Massaro (1975), is:

> ... a number of mental operations, called processing stages, occur between stimulus and response. A stimulus has potential information and its presentation initiates a sequence of processing stages in which each operates on the information available to it (pp.19-20).

Within the information processing framework, reading psychologists have developed a number of models of the reading process. These models all have in common a view of the reading process as a series of processing stages that occur between written symbols and meaning. The major distinction centers around the question of whether reading is regarded as a top-down or a bottom-up processing activity. Top-down models conceive reading as mainly a concept-driven process. In contrast, bottom-up models assume reading as primarily a stimulus-driven process (Downing & Leong, 1982). Whereas these two types of models have focused on analysis of component processes of reading in one direction, interactive models, which allow both bottom-up and top-down processing, emphasize the interactive nature of the components (Stanovich, 1980). These three types of models will be described as follows with emphasis on the role of word identification in each of these models.

2.1.1.1 Top-down models

According to top-down models, the direction of processing is from the cognition system downward to the stimulus. The reader acts like a hypothesis tester, using his/her conceptual and linguistic knowledge to form hypotheses about what is being read and sampling textual information to confirm or reject the hypotheses. Hence, the reader's knowledge relevant for the content of the text opens the door to comprehension whereas a detail analysis of print (e.g. analysis of letters, letter clusters, words and so on) is not considered necessary for comprehension. This conceptually driven process of reading has been strongly emphasized by Goodman (1970, 1976) and Smith (1978, 1979).

Goodman (1970) describes reading as a "psycholinguistic guessing game" requiring the reader to interrelate language and thought in an effort to reconstruct the author's written message. He regards the reader's expectation as most important and deemphasizes precise analysis of letters, words, or phrases in the process of reading. Goodman (1970) states:

> Reading is a selective process. It involves partial use of available minimal language cues selected from perceptual input on the basis of the reader's expectation. As this partial information is processed, tentative decisions are made to be confirmed, rejected, or refined as reading progresses.
> ... Efficient reading does not result from precise perception

> and identification of all elements, but from skill in selecting the fewest, most productive cues necessary to produce guesses which are right the first time (p.260).

Smith (1978, 1979) holds a similar view to that of Goodman in that reading is essentially a process of hypothesis-testing. Whereas Goodman describes reading as a "psycholinguistic guessing game", Smith (1979) asserts that "reading is asking questions of printed text"(p.105). In order to get questions answered, the reader must make maximum use of his 'nonvisual information' and reduce the use of 'visual information'. Smith (1978) contends:

> ... reading is possible only when the reader can bring sufficient nonvisual information to bear to reduce the amount of visual information that must be attended to in the text, or at least to utilize the visual information as enconomically and efficiently as possible (p.178).

'Nonvisual information', to Smith, is the reader's relevant prior knowledge for the content of the text, and 'visual information' is the surface structure of print. The basic skill of reading, therefore, lies more in the reader's conceptual knowledge than in identification of elements of print. This conception of reading skill has led Smith (1979) to argue that "the apprehension of meaning can precede the identification of individual words" and that "normal reading demands comprehension prior to and even without the identification of words"(p.119).

In brief, both Goodman and Smith emphasize the top-down approach to reading. Reading subprocesses at the word and subword level are deemphasized. To these top-down theorists, word recognition is neither definitive nor essential to reading comprehension.

Many researchers (e.g. Perfetti, 1980, 1983; Singer, 1982; Stanovich, 1980, 1984), however, have criticized these top-down models for their vagueness in conceptualization and their deficiency in explaining competent reading. As they have pointed out, while the contribution of conceptual knowledge to successful reading is recognized, it should not be regarded as the sole factor affecting reading achievement. In other words, a skilled reader's use of higher-level information does not eliminate the importance of other sources of information in fluent reading. This idea has led Singer (1982) to argue that "their (Goodman's and Smith's) attack on the importance of decoding to competent reading reflects their inability to accept the heterogeneity of reading disability and the variety of factors implicated in competent reading"(p.48).

2.1.1.2 Bottom-up models

For bottom-up theorists, the direction of processing is from analyzing data up to meaning. The reader is viewed as an analytic processor of print, making use of perceptual, phonological and morphological analysis to generate meaning from the text. Accordingly, the reader's recognition at the word and subword level serves as a preliminary processor to facilitate reading, and is considered prerequisite for comprehension. This stimulus-driven process of reading is stressed by Gough (1972, Gough & Cosky, 1977), and Laberge and Samuels (1974; Samuels, 1977; Samuels and Laberge, 1983).

According to Gough (1972), reading is a serial-stage process of letter-by-letter, word-by-word, sentence-by-sentence analysis of print. Holding a viewpoint in opposition to top-down theorists on the reading process, Gough (1972) argues:

> ... the reader is not a guesser. From the outside, he appears to go from print to meaning as if by magic. But I have contended that this is illusion, that he really plods through the sentence, letter by letter, word by word (p.354).

Gough attempts to describe what transcribes in one second of skilled reading. For him, as readings begins, the visual information perceived by the reader is first formed as a precategorical visual image, an icon. Serial identification of letters follows, one by one from left to right. Letters are then coded into a string of systematic phonemes by which the reader searches meanings for the words in his mental lexicon. The process of lexical search, again, is one word by one word from left to right. The reader then stores the words in primary memory to await the next process, sentence comprehension. Finally, when enough words have reached the comprehension device, a sentence emerges complete with its semantic referents. Thus, the reading process in Gough's model is strictly bottom up, from lower-level sensory analysis to higher-level syntactic-semantic encodings. A similar though more flixible serial-stage model of reading is proposed by Laberge and Samuels (1974).

The LaBerge and Samuels (1974; Samuels, 1977, 1982; Samuels and LaBerge, 1983) model has the general characteristics of a serial-stage theory. It describes the reading process in terms of a series of processing stages, from visual input, to feature detection, to letter coding, to spelling pattern coding, to visual word coding, to phonological word coding, to semantic word coding and ultimately to sentence comprehension.[1] But unlike the Gough model, the LaBerge and Samuels model is more flexible in that it accommodates a variety of processing routes and allows certain stages to be skipped. For example, a visually presented word can be accessed for meaning with or without phonological coding. More important, what makes the LaBerge and Samuels model distinct from other serial-stage models is its emphasis on the role of attention and the notion of automaticity in reading.

---

[1] It should be noted that when the LaBerge and Samuels model was first published in 1974, it suggested that the flow of information would be in a linear direction from visual memory to phological memory to semantic memory without feedback loops to one and other. Nevertheless, since Rumelhart (1977) has shown that components in a system can interact and share information with another component, feedback loops among visual memory, phonological memory, and semantic memory were added in the model (Samuels, 1977). Recently, in their retrospective analysis of the model, Samuels and Laberge (1983) concede that the linearity of the model is the aspect they would like to revise.

According to LaBerge and Samuels (1974), there is a limit to the amount of attention available for any time period. Because of the limited-capacity property of attention, one can only attend to one thing at a time. Nevertheless, one may be able to process many things simultaneously, if no more than one thing requires attention. When a behaviour can be performed without attention, it is considered 'automatic'. How can this notion of automaticity be related to the reading process? For Laberge and Samuels, reading involves many lower-level subskills, such as letter and word recognition, and higher-level subskills, such as use of context cues in comprehension. Put it in a simplier way, reading can be viewed as a two-step process consisting of lower-level task -- decoding, and higher-level task -- comprehension (Samuels, 1977). Since the amount of attention is limited, if decoding consumes too much attention, there will not be enough attention available for comprehension. On the contrary, if the decoding process requires very little attention, the bulk of the attentional resources can be used for comprehension. Samuels (1982) contends:

> When the decoding task requires very little attention and the student can decode and comprehend at the same time, we say that the student is automatic at decoding. Although automaticity in decoding will not guarantee good comprehension, it can be considered to be a prerequisite for skilled reading. ... Lack of automatic decoding is a common problem leading to reading difficulty ... (p.234).

In other words, automaticity in lower-level processing frees the reader's limited attention capacity to be centered on comprehension. The faster and more automatically that the lower-level processes can be performed, the more attention is made available to accomplish the higher-level comprehension process. The importance of automaticity in reading, thus, represents the characteristic of the LaBerge and Samuels model.

In short, both the Gough model and the LaBerge and Samuels model (1974, before the 1977 and 1983 revision) are typically bottom-up processing oriented. They view discriminant analysis of letters, letter groups, and words, as primary in the reading process. Accordingly, word identification plays a critical role in reading. It is assumed to be at least necessary for efficient reading.

While emphasizing the primacy of lower-level subskills, bottom-up theorists have not therefore denied the contribution of higher-level subskills to fluent reading. As Samuels (1977) has pointed out:

> The ability to get the meaning of each word in a sentence, however, is not the same as what is meant by comprehending a sentence. ... Whereas one may go from print to the meanings of individual words automatically, it is the act of integrating, relating, and combining these meanings in the unique ways demanded by sentences that is required (p.19).

In this sense, bottom-up models may be considered superior to top-down models in handling the variety of factors implicated in fluent reading. But still, bottom-up models are no more adequate than top-down models in conceptualizing the reading process in that both these two types of model appear to offer dichotomous descriptions of the reading process. While top-down models necessarily move from the higher to lower levels of the processing sequence and neglect the contraints of lower-analyses to higher-level processes, bottom-up models imperatively begin from the lower to higher levels of the processing hierarchy and fail to account for the impact of contextual processing on lower-level analyses (Rumelhart, 1977; Stanovich, 1980). In view of the deficiencies of strictly top-down and bottom-up models, a third class of theory emphasizing the interactive nature of the component skills in reading has emerged.

2.1.1.3 Interactive models

Interactive models differ from top-down or bottom-up models primarily in terms of the executive control of processing. For interactive theorists, reading is not necessarily a linear process. The executive control of processing, therefore, is neither top-down nor bottom-up. Rather, "data-driven, bottom-up processing combines with top-down, conceptually driven processing to cooperatively determine the most likely interpretation of the input" (Rumelhart & McClelland, 1981, p.37). In other words, information from any level may interact with any other higher or lower level as the reader searches for meaning. This interactive aspect of reading is emphasized by Rumelhart (1977), Lesgold and Perfetti (1978), and Stanovich (1980).

Based on language processing by computer, Rumelhart (1977) has outlined a reading model which makes use of formalism allowing parallel, interactive processing units. In his model, 'top-down' and 'bottom-up' refer not so much to processes as to sources of information. He separates six levels of knowledge source -- feature, letter, letter cluster, lexical, syntactic, and semantic levels -- each of which is responsive to one dimension of a text. Although it may be possible to devise a heirachical ordering of these levels of analysis involved in reading, Rumelhart stresses that knowledge at all these levels is active simultaneously in specifying the input information. Each of these levels forms hypotheses from the data available, and sends hypotheses to a central devise (message center) where information can be shared for integration at other levels. In a word, reading is interactive because different levels of processing are responsible for providing information and sharing the information with other levels. Comprehension, as a result, is the process of synthesizing information provided simultaneously from all levels. Rumelhart has described his model as a heuristic one, as it simply outlines a formalism within which more detailed models can be built rather than specifying a set of proposed processes.

Consistent with the assumption that reading is interactive, Perfetti and Lesgold (1977, 1979; Lesgold and Perfetti, 1978; Perfetti, 1985a,b) have developed a model of reading skill emphasizing verbal efficiency. Like Rumelhart, Lesgold and Perfetti (1978) agree that "comprehension during reading involves higher-order processing of discourse structure and the reader's knowledge in interaction with lower-level word coding processes. The interaction between these 'top-down' and 'bottom-up' processes must be taken into account in models of comprehension"(p.323). To illustrate the need for an interactive view of the reading process, Lesgold and Perfetti (1978) describe bottom-up theorists as surgeons and top-down theorists as internists:

> The bottom-up view, more surgical, traces the flow of coding information between connected components. the top-down view, more medical, concentrates on the higher-level goals of reading. Both viewpoints are needed, but both must proceed from a common general interactive model of the reading process (p.325).

Despite the emphasis on the mutually supportive interplay between bottom-up and top-down processing, however, an asymmetry between these two levels of processing is proposed. The use of top-down and bottom-up data is not strictly reciprocal (Perfetti, 1980). A detailed explanation of this central assumption of the model is presented by Perfetti and Roth (1981). They point out that although higher-level processes can begin with very little data provided by lower-level processes, the higher-level processes cannot rise above zero, that is, prior to the beginning of lower-level processes. In this sense, lower-level processes (e.g. lexical access) are rate limiting for higher-level processes (e.g. semantic parsing). In contrast, influences of higher-level processes on lower-level processes are essentially rate-constant effects. While higher-level processes can make lower-level processes more efficient (e.g. words can be recognized more quickly in context), "they do not affect the dependence of higher-level processes on logically prior, lower-level ones" (Perfetti & Roth, 1981, p.270). In brief, according to the verbal efficiency model proposed by Perfetti and his associates, reading processes are interactive but asymmetrical. Consequently, "bottom-up processes can carry on reasonably well without top-down processes, but not vice versa" (Perfetti & Roth, 1981, p.271). It is not surprising that an interactive model based on such an assumption has some essential characteristics similar to those of the Laberge and Samuels model.

Whereas attention plays a similarly important role in the verbal efficiency theory as in the Laberge and Samuels model, Perfetti and Lesgold (1979) have further formed a bottleneck hypothesis stressing the limited capacity of working memory. The main idea of this hypothesis is that reading comprehension processes share working memory resources with lower-level word processes. A processing bottleneck is created when the capacity of working memory is reached. To relieve this bottleneck, the resources devoted to word coding processes can be reduced by increasing the efficiency of word recognition. In short, the bottleneck hypothesis assumes that single-word coding operations are a crucial part of reading and that the faster the decoding processes can be executed, the more working memory resources are available for integrating comprehension processes.

Relating this bottleneck hypothesis to reader ability differences, Lesgold and Perfetti (1978, p.320) suggest that "the interfering effect of slow, inefficient word-code access on execution of higher-level components of the reading process" is a major source of individual skill differences in reading comprehension. In their view, slow coding processes deactivate memories of recently established contexts and therefore disrupt comprehension.

In his recent writings, Perfetti (1984a,b; 1985a,b) has given a more complete account of the verbal efficiency theory as a framework for understanding reading ability. While maintaining the general proposal of the theory as described above, Perfetti (1985a) provides some more specific components of verbal efficiency. He states that there are two classes of hypotheses for explaining individual differences in verbal efficiency. One possibility is that ineffective lexical access which affects working memory is responsible for observed differences in memory and lexical processes. This hypothesis has been made in previous versions of the theory (e.g. Perfetti & Lesgold, 1977, 1979). The alternative explaination is that intrinsic working-memory differences are responsible. Perfetti notes that both are reasonable elaborations of verbal efficiency. To accommodate these two hypotheses compatibly, Perfetti (1985b) further proposes "a generalized linguistic coding process that affects the speed and quality of both the lexical access and the manipulation of codes in memory"(p.120). According to Perfetti, an inefficient linguistic coding mechanism may inhibit verbal efficiency by providing lexical access interference, low-quality word codes and incomplete propositional encoding, and thus interfer with comprehension.

In discussing the exact sources of ability differences in lexical access, Perfetti (1984a, 1985a,b) hypothesizes that linguistice processes concerning orthographic patterns and speech components may be involved. For example, the knowledge a reader has about permissible letter patterns is a potentially important level of knowledge of orthographic patterns. With regard to speech components, Perfetti (1985a,b) assumes that speech codes are automatically activated as part of lexical access and play the role of reference securing to aid memory and comprehension. It is likely that inefficient lexical access would result in low-quality phonological codes that are vulnerable to memory loss by succeeding coding operations. Perfetti (1985a) postulates that speech processes may play a significant role in reading but at the same time recognizes that the degree of phonological involvement in reading remains an open issue.

Furthermore, an important point concerning context and word recognition is added in the later versions of the theory (Perfetti & Roth, 1981; Perfetti, 1984a,b; 1985a,b). By assuming that reading is an interactive act, Perfetti points out that there are procedures to be applied to compensate for inefficiency of lower-level processes. For example, to a certain extent inefficient lexical access can be overcome by schema-based processes. Therefore, it is possible that less-skilled readers, due to inefficient lexical access skills, will be more dependent on context for word recognition than skilled readers.

Finally, Perfetti (1984a, 1985a) argues that the verbal efficiency theory does not deny the importance of higher-level cognitive structures such as schemata for comprehension. Neither does it imply that all comprehension problems are traceable to word recognition or coding problems. All in all, what the theory offers is the principle of the primacy of verbal coding as an essential part of a model of skilled reading.

While acknowledging that Rumelhart (1977) provides the best example of an interactive model, Stanovich (1980) further suggests an interactive-compensatory model based on Rumelhart's proposal.

Comparing Rumelhart's interactive model to most top-down and bottom-up models, Stanovich (1980) argues that the interactive model is superior in that it allows a compensatory hypothesis which can better account for much research evidence of the reading literature. In top-down models, lower-level processes depend on higher-level processes and in bottom-up models, vice versa. Since no interactions among processes are implied, a compensatory mechanism is not possible in these two types of model. In contrast, the interactive model developed by Rumelhart stresses the relative independence of processes at different levels and therefore suggests a possiblity that a deficit in any processing level may result in a heavier reliance on any other processing levels. Combining the compensatory assumption with Rumelhart's interactive model, Stanovich (1980) proposes an interactive-compensatory model of reading, stating:

> A compensatory-interactive model of processing hypothesizes that a pattern is synthesized based on information provided simultaneously from all knowledge sources and that a process at any level can compensate for deficiencies at any other level (p.262).

Discussing individual differences in reading fluency in view of current theoretical models, Stanovich argues that his model leads to a reconceptualization of the nature of individual differences in reading. In both top-down and bottom-up models, higher-level processes are usually less implicated in the performance of poor readers. Nevertheless, Stanovich invalidates this conception by pointing out that it is important to distinguish at least two types of contextual processing. While context can be used to aid comprehension of text, it can also be used to facilitate word recognition during reading. It is this latter type of context effect on which poor readers may show greater reliance than do good readers, usually a result of poor readers' inefficient decoding skills. Hence, according to the interactive-compensatory model, the reader extracts meaning from text based on information provided simultaneously from several knowledge sources. When word identification is inefficient, the reader may draw from higher-level knowledge sources to aid recognition. However, while this kind of compensatory use of contextual information may facilitate performance at the word level, it will deplete the cognitive resources available to integrative text-level processes, and therefore eventually the comprehension of the reader may suffer.

Stanovich admits that his interactive-compensatory model is closely related to the automaticity model developed by LaBerge and Samuels (1974), and the verbal efficiency model proposed by Perfetti and Lesgold (1977). All of these three theories propose that efficient lower-level processes can free capacity for comprehension processes. Thus, these three models are in agreement that fast and automatic word recognition is an important determinant of reading ability. Nevertheless, the major difference among the three, according to Stanovich, is that only the interactive-compensatory model contains a mechanism for interactive-compensatory processing at the level of word identification.[2] By presenting a thorough review of the research literature on individual differences in reading, Stanovich (1980) argues that the interactive-compensatory model best accounts for much research evidence disclosing a pattern of poor word recognition skills, use of context to facilitate word recognition, and poor comprehension on the part of the less skilled reader.

2.1.1.4 Summary of reading models

Current theoretical models of the reading process differ in the extent to which they view the flow of information processing. Top-down models stress the importance of higher-level processes in directing lower-level processes. Bottom-up models assume that the direction of processing is from data analysis up to higher-level contextual encodings. Interactive models permit both top-down and bottom-up processing.

Despite the differences among these models, the speed of processing is commonly recognized as being crucial to reading. Top-down models argue that individual word identification should be deemphasized (i.e., words should only be sampled from text) in order to have rapid processing speed at the text level. Bottom-up and interactive models, however, contend that processing speed at the word level is an important determinant of reading proficiency. While strictly top-down or bottom-up models have been criticized as inadequate in conceptualizing the reading process, most theoretical arguments just reviewed favour a direct relationship between efficient word recognition and reading comprehension ability. It appears that on theoretical bases there is sufficient ground to hypothesize that word recognition skill is an important determinant of fluency in reading comprehension. Still, we need to turn from theory to research to examine the empirical relationships between word recognition skill and reading ability.

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[2] It should be noted that the interactive-compensatory hypothesis, though not included in the earlier versions of the verbal efficiency model, does appear in the later versions (Perfetti & Roth, 1981; Perfetti, 1985b). Also, Perfetti (1984a,p.54) claims that Stanovich's interactive-compensatory model is fully compatible with the verbal efficiency theory.

2.1.2 Empirical research in reading English

During the past decade, interest in the psychology of reading has spawned a large number of studies that have attempted to determine the importance of word recognition as a component of reading. Presented below are some basic research of eye movements on lexical access in reading, and major studies concerning the relationships between word recognition and reading ability in regards to word recognition automaticity, word recognition speed, and word recognition in context.

2.1.2.1 Eye movement research

The notion that word recognition is an important part of the reading process, as assumed in most of the reading models previously discussed, has gained support from studies of eye movements by Just and Carpenter (1980; Carpenter & Just, 1981), and by Rayner (1975, 1978, 1983).

In an attempt to develop a process model of reading, Just and Carpenter (1980) examined the gaze durations of college students while reading.

The data presented in their study showed that during ordinary reading, contrary to the general impression that readers skip words, most words in the text are directly fixated. In their later report, Carpenter and Just (1981) noted that over 80% of the content words and many function words in the text are fixated. Moreover, the duration of fixation is affected by word length and frequency. Whereas long words are fixated longer than short words, low frequency words are fixated longer than high frequency words.

Why are frequent fixations needed during normal reading? This may be due to the narrownesss of the perceptual span. Using a visual display which could be changed on any given location to detect the changes of a subject's eye fixation, Rayner (1975, 1978) reported that when letter alternation was beyond three character spaces to the right, it had little effect on the reader's eye fixation. Also, it was found that, although information about word shape and length can be obtained out to about fifteen spaces from the fixation, readers generally cannot determine the meaning of a word that is in the visual periphery (Rayner, 1983). Rayner's studies indicated that the perceptual span for specific word recognition is only a few letters and that readers do not get much information beyond the center of fixation.

In sum, eye movement research shows that the perceptual span in reading is quite narrow and that most words are fixated during normal reading. The studies described above demonstrate the central importance of lexical access in reading; reading cannot occur without reading words.

2.1.2.2 Studies of word recognition automaticity

Empirical tests of the automaticity model of reading developed by Laberge and Samuels have been undertaken since its presentation in 1974. Many investigators have employed Stroop-like tasks to study the development of automatic processing. As pointed out by Stanovich, Cunningham, and West (1981), the rationale is:

> In the Stroop task subjects are asked to name the color of the ink in which a string of stimuli is printed. When the string is a series of letters that spell the name of a conflicting word (e.g. the word "red" written in blue ink), color-naming is much slower than in a control situation where the string consists of nonverbal stimuli. This color-word interference effect is usually explained in terms of the competition between vocal responses to the printed word and the ink color. Since the subjects engaged in a Stroop task are attempting to attend only to the color of the ink, color-word interference is presumably the result of the word that has been read automatically.
>
> ... If, as suggested by automaticity theory, skilled readers process words more automatically than less skilled readers, a larger Stroop effect might be expected for the more skilled readers (p.58).

Several studies using the Stroop-type paradigms have provided some indication that less-skilled readers tend to process words less automatically than skilled readers. Using a picture-word interference task which is a variant of the Stroop paradigms, Ehri (1976) found that, except for a group of below-average second-grade readers, interference was evident in average second graders, fifth graders, and adults. Also using a picture-word interference task, Pace and Golinkoff (1976) reported that skilled third-grade readers took a longer time to respond than did less-skilled readers of the same grade on processing difficult interference words, though they failed to find a similar relationship in fifth graders. Employing the same research paradigm, Guttentag and Haith (1978) found that poor third-grade readers decoded unfamilar letter strings much less automatically than good third-grade readers. Using adults as subjects, Martin (1978) reported that fast readers showed larger interference effects than did slow readers on a Stroop color-word task.

While the studies reviewed above have provided some support to the predictions of the automaticity theory regarding individual differences, results from many developmental studies also using the Stroop-type paradigms have shown that word recognition process seems to become automatized much ealier than would be expected from the LaBerge and Samuels model. In the West and Stanovich (1979) study and the study by Schadler and Thissen (1981), kindergarteners had fully automatized the recognition of letters. Marked increases in automaticity during the first grade were reported in both cross-sectional studies (Guttentag & Haith, 1978, 1979; Schadler & Thissen, 1981; West & Stanovich, 1979) and longitudinal studies (e.g. Stanovich, Cunningham, & West, 1981). Investigating a wide age range, Rosinski, Golinkoff, and Kukish (1975) observed the same amount of Stroop effect in second graders as in adults. Using a picture classification task, Guttentag and Haith (1979) found that all three subject groups (second graders, third graders, and adults) automatically processed the irrelevant printed words. All of these studies have provided converging evidence that automatic word processing emerges as early as the first or second grade, much earlier in reading acquisition than assumed in the automaticity model.

Furthermore, an important characteristic of the developmental trend of word recognition automaticity in most of the above mentioned studies is the developmental decrease in interference. Ehri (1976) found decreases in Stroop effect between skilled second-grade readers and fifth graders, as well as between fifth graders and adult readers. Guttentag and Haith (1979) reported an overall age-related decrease in interference effect when comparing second graders, third graders, and adults. Less interference for third-graders than for first graders was also observed in the West and Stanovich (1979) experiment. Schadler and Thissen (1981) did report increases of interference from the second- to fourth-grade reading levels, but the whole study demonstrated a developmental sequence of interference effect -- "interference with color naming begins to emerge early in the process of learning to read, increases, and then subsequently decreases"(p.132) -- which is similar to that found in other studies.

Although the developmental decrease of interference was evident in a number of studies, there have been few attempts to explore its nature. Ehri and Wilce (1979) may be among the first researchers who have attempted to tackle the issue. They propose that three subsequent phases comprise the development of word recognition skill: accuracy, automaticity, and speed. However, researchers studying the development of word recognition skill, argued Ehri and Wilce, have often failed to separate the attainment of automaticity from the attainment of speed. In their study, Ehri and Wilce attempted to distinguish between these two phases of word learning. At the outset of the experiment, they gave first and second graders a test on a picture-word interference task. Following the test, they gave the subjects word recognition training with the set of interfering words. On a separate day, the subjects were again tested with the picture-word interference task. Ehri and Wilce found that word training increased the amount of interference for subjects who were less familiar with the interfering words and learned to recognize them during training, but decreased interference for those who were already familiar with the interfering words prior to training. Ehri and Wilce hypothesized that training enabled children in the first group to begin to process the words automatically and therefore increased the amount of interference on the picture-word task, whereas practice enabled children in the latter group to recognize the word they already knew more rapidly and thus reduced the delay in processing created by the interfering words in the picture-word task. These findings, according to Ehri and Wilce, have revealed the distinction between the attainment of word recognition automaticity and the attainment of word recognition speed.

Stanovich, Cunningham, and West (1981) also argue for the distinction between speed and automaticity to be made by reading theorists. In their longitudinal study, first graders performed a Stroop task three times (September, Feburary, and April) during the school year. The researchers found that there was a salient increase in interference in mid-way during the first grade but there was little change by the end of the year. These results, argued Stanovich, Cunningham, and West, indicate that the automaticity function had began to level off by the end of the first grade. Moreover, while there was a tendency for the skilled readers to show more interference and to exhibit interference earlier in the year, the correlations between the interference ratios and reading ability measures were small in size and generally nonsignificant. In contrast, word naming speed was highly correlated with the same reading ability measures. Hence, although the pattern of results was modestly consistent with the automaticity theory, the trends appeared to be rather weak. The researchers hypothesized that by the end of the first grade the skilled readers in their research had fully automatized the recognition of words used in the experiments and their further progress in reading was more dependent on the development of speed rather than automaticity. As pointed out by Stanovich et al. (1981), one important implication of their study was that "word recognition speed continues to increase even after recognition has become automatized"(p.725). This may reasonably explain the developmental decrease of interference observed in the previous studies. It is possible that interference decreases because the recognition time with which the interfering words are processed continues to decrease after the child has learned to automatically process the words.

In summary, some studies reviewed above have indicated that skilled readers show a greater tendency to process words automatically. Nevertheless, a number of developmental studies have failed to find an increase in automatic word processing after the second- or third-grade reading level has been reached. Moreover, the studies of Ehri and Wilce (1979) and Stanovich, Cunningham, and West (1981) have all pointed to the importance of making the distinction between automaticity and speed in word recogntion. In light of the findings from the research reviewed above, it appears that beyond the initial levels of reading skill development, it is word recognition speed rather than automaticity that is the more significant factor accounting for reading ability. As pointed out by Haines and Leong (1983), while the automaticity model remains a powerful model in explaining individual differences in reading fluency, the focus of current research in this area is more on verbal knowledge than on automaticity in terms of overcoming competing attention. It is, therefore, reasonable to review the studies focused on word recognition speed and reading ability.

2.1.2.3 Studies of word recognition speed

The ability to identify words accurately and rapidly is highly correlated with reading proficiency, as revealed in a wide variety of studies investigating children as well as adult readers.

Examining oral reading errors of second, third, and fourth graders, Shankweiler and Liberman (1972) found a moderate-to-high relationship (correlations ranging from .53 to .77) between word reading accuracy and reading proficiency as measured by the Gray Oral Reading Test. The investigators further obtained word recognition latency measures for one group of third graders and found that latency measures and error counts showed an equal degree or negative correlation with Gray reading performance. From these results, Shankweiler and Liberman (1972) suggested that the slow rate of reading individual words may contribute as much as inaccuracy to poor paragraph reading performance.

In a longitudinal study of the early prediction of reading and arithemetic achievement during the first three grades in elementary school, Stevenson, Park, Wilkinson, Hegion, and Fish (1976) also reported high correlations between word reading tests and comprehension tests. They found that the ability to read words on the Wide Range Achievement Test was highly related to comprehension of paragraphs on the Gray Test for second graders and to comprehension on the Stanford Achievement Test for third graders. The correlations were approximately .78 for second graders and .80 for third graders.

In agreement with the findings of the above two studies, Groff (1978) observed high correlations ranging from .71 to .96 between word reading and sentence/paragraph reading scores for several other elementary grade standardized reading tests such as Achievement Tests in Silent Reading, Silent Reading Diagnostic tests, Slossen Oral reading Test, and Woodcock Reading Mastery Tests, etc.. It should be noted that the correlation as high as .96 is questionable. Nevertheless, Groff's findings were consistent with other studies showing a substantial relationship between word recognition and comprehension ability.

An extensive study reported by Biemiller (1977-78) demonstrated that letter and word perception is an important part of reading. Biemiller (1977-78) examined oral reading speeds for letters, words in isolation, and words in context for good and poor readers. Using groups of readers from grade two through adult and materials ranging from a primer to college texts, large time lags were found for poor readers, especially when they were required to read words in isolation. More specifically, Biemiller (1977-78) found that 80 to 90% of text reading time variance was accounted for by letter and word reading times in grade three to five, with an average of 68% of the variance accounted for by letter and word reading times in second through sixth grade. From his findings Biemiller hypothesized that some minimal level of basic identification speed may be crucial for success in reading.

Using second graders as subjects, McCormick and Samuels (1979) reported that word recognition accuracy and latency were each significantly correlated with comprehension ability as measured by Gray Oral Reading Tests and Science Research Associates Achievement series. The correlations between word recognition accuracy and comprehension ranged from .49 to .70 whereas the correlations between word recognition latency and comprehension ranged from -.54 to -.56.

A more recent study by Deno, Mirkin, and Chiang (1982) also revealed a high correlation between word recognition accuracy and reading proficiency. The researchers conducted three concurrent validity studies to determine the relationship between performances on formative measures of reading and standardized reading tests. Five formative measures -- words in isolation, words in context, oral reading, close comprehension, and word meaning -- were constructed. Also, three standardized reading comprehension subtests from the Standford Diagnostic Reading Test, Woodcock Reading Mastery Tests, and Peabody Individual Achievement Test were selected. The performance of regular and resource program students in grade one through grade six on these measures was then investigated. The researchers found that three reading aloud measures -- words in isolation, words in context, and oral reading -- all related closely to performance on standardized reading tests. The correlations ranged from .73 to .91.

In short, in the aforementioned studies, where correlational analyses were used to explore the relationships among word recognition accuracy and latency and comprehension ability, results showed that the absolute values of the correlations have been in the range of approximately .50 to .80. These findings indicate that high accuracy and speed of word recognition are associated with high comprehension.

In a different kind of research paradigm, where vocalization tasks and/or lexical decision tasks were employed, results also pointed to the evidence that fast accurate word recognition is a skill which consistently differentiates good from poor readers. Good examples of this type of research are those carried out by Perfetti and his colleagues (Hogaboam & Perfetti, 1978; Perfetti, Finger, & Hogaboam, 1978; Perfetti & Hogaboam, 1975), Curtis (1980), Stanovich (1981), and Haines and Leong (1983), among others.

Perfetti and his colleagues at Pittsburgh have conducted a series of studies on children from grade two through six. In one of the studies, Perfetti and Hogaboam (1975) placed third and fifth graders into skilled and less-skilled reader groups using the reading subtest of the Metropolitan Achievement Test. The researchers then measured vocalization latencies for high and low frequency words and pseudowords. They found that in all cases skilled readers had shorter vocalization latencies than less skilled readers at both grade levels. Moreover, while skilled and less skilled readers showed smaller vocalization latency differences (approximately 200 msec) for high frequency words, skilled readers were far more superior (approximately 1 sec faster) in vocalizing low frequency words and pseudowords. These results, according to Perfetti and Hogaboam (1975), suggested the importance of word decoding skills in reading comprehension, at least in the middle grades tested in the study.

The Perfetti and Hogaboam (1975) study was replicated by Marr and Kamil (1981). They examined third and fifth graders' decoding of words which varied in both length (4-5-6 letters) and word frequency (high-medium-low). The study replicated the basic findings of Perfetti and Hogaboam (1975), that skilled readers are faster in decoding words. Also, the results in this study revealed the significant effects of word length and word frequency upon decoding for both reader groups. In brief, Marr and Kamil's replication has served to verify the relationship between single word decoding and reading comprehension ability reported by Perfetti and Hogaboam (1975).

In another series of experiments, Hogaboam and Perfetti (1978) examined the effects of subword units and word experiences on readers' word decoding speeds. Using third- and fourth- graders as subjects, the researchers observed that the vocalization latencies of less skilled readers were more affected by the number of syllables in a word than those of skilled readers. The average difference between one- and two- syllable words ranged from 240 to 330 msec for skilled readers, and it was about 780 msec to 1 second for less skilled readers. These results indicated that subword decoding processes are a source of decoding differences between skilled and less-skilled readers. Nevertheless, the differences between skilled and less skilled readers may be due to differential word experiences. To evaluate this possibility the researchers conducted a second experiment in which skilled and less skilled fourth-grade readers were provided with equal amounts of aural, visual, and semantic experiences with pseudowords. The effects of these experiences on decoding latencies were then observed. Hogaboam and Perfetti found that aural and visual experiences with pseudowords led to shorter vocalization latencies for both skilled and less-skilled readers, but meaning experience added nothing. While the qualitative patterns were similar, there were some quantitative differences in the effect of these experiences on skilled and less skilled readers. Equal experiences did not lead to equal reaction times. Skilled readers were always faster in decoding words even when both quantity and quality of previous word experiences were equated. The results suggested that decoding differences between skilled and less skilled readers are not wholly attributable to differential word experiences. In their third experiment, Hogaboam and Perfetti further investigated the effect of varying the quantity of word experiences. Skilled and less skilled third-grade readers received aural and visual experiences with pseudowords a predetermined number of times, varying from zero to eighteen spread over three days. In the decoding tests that followed, skilled readers were faster for all values of the frequency variable. More important, skilled readers benefited greatly from minimal (three) aural exposures, whereas a greater frequency was needed for less skilled readers to show any gains in decoding speed. From these results Hogaboam and Perfetti argued for phonological coding components being involved in determining reading abilities.

In order to further examine sources of vocalization latency differences between skilled and less skilled readers, Perfetti, Finger, and Hogaboam (1978) tested skilled and less skilled third-grade readers on their ability to name words, colours, digits, and pictures. They found that only in tasks involoving words were there significant differences between skilled and less skilled readers. Less skilled readers named colours, digits, and pictures in a similar rate as did skilled readers. Nevertheless, they were much slower than skilled readers in naming words, specially when multisyllable words were presented. Since differences between skilled and less skilled readers in vocalization latencies occurred only for alphabetic stimuli but not for nonalphabetic materials, the investigators suggested that it is not general processing-speed capabilities that differentiate skilled from less skilled readers. Rather, less skilled readers are deficient in coding processes specific to alphabetic inputs.

Stanovich (1981) conducted an analogous study to that of Perfetti et al. (1978). Instead of using third grade children who were well beyond the beginning stages of reading acquisition, Stanovich utilized first-grade readers to see whether or not similar results would be observed for children in the acquisition stage. Furthermore, a letter condition was added to the conditions employed by Perfetti et al. (1978), in an attempt to determine whether the ability to discriminate the elements of words in isolation or the ability to decode the structure of words is the crucial factor distinguishing skilled from less skilled readers. Results of the Stanovich (1981) study were highly convergent with the findings obtained by Perfetti et al. (1978). No significant differences in digit, colour, picture, or letter naming were found between the two reader groups. Words were the only stimulus type that skilled readers named much faster than less skilled readers. For Stanovich, the marked word naming speed difference in conjunction with the lack of a letter naming difference between the two reader groups indicated that phonological analysis skill may be more critical than visual processing abilities in determining early reading success.

The data of the Ehri and Wilce (1983) study, however, were not completely consistent with the pattern of results of the just mentioned three studies. Ehri and Wilce investigated the development of word recognition speed in children of different grades. They contended that, as discussed earlier in their 1979 study, word identification skill can be divided into three stages: acquisition, automaticity, and speed. Moreover, when components (i.e., graphic, phonological, semantic) of the identification process are integrated in memory for particular words, the unitized speed (i.e., maximum speed) in identifying these particular words is said to be attained. The researchers asked skilled and less skilled readers in first, second, and fourth grades to name digits, pictures, familiar words, and consonant vowel-consonant (CVC) nonwords. The attainment of unitized speeds to words was inferred if subjects recognized words as rapidly as digits. They found that unitized speed with familiar words were displayed by skilled readers in all grades but by less skilled readers only in fourth grade. In addition, unitized speed with CVCs was found in skilled readers of second and fourth grades, but not in less skilled readers at any grade. These findings were consistent with previous studies indicating that rapid word recognition distinguishes skilled from less skilled readers. Nevertheless, whereas Perfetti et al. (1978) and Stanovich (1981) observed no differences in digit and picture naming speed between skilled and less skilled readers, Ehri and Wilce uncovered differences. Skilled readers named both pictures and digits significantly faster than did less skilled readers.

Picture naming difference between skilled and less skilled readers has also been found by de Soto and de Soto (1983). These investigators tested verbal processing abilities in grade four achieving and nonachieving readers through various tasks such as memory span, associate learning, semantic association, automatic word processing, and naming speeds of pictures, words, and pseudowords. It was found that achieving readers performed better on all tasks except automatic word processing. The investigators suggested that the interfering words in the automatic word processing task were familiar enough to be automatically processed by both achieving and nonachieving readers since they were beyond the initial stages of reading acquisition. This finding was in agreement with previous research on automatic word processing, as reviewed before. Another major finding of this study was that rapid verbal coding of visual stimuli is an important component differentiating achieving from nonchieving readers. Moreover, of all the verbal coding measures, the ability to read pseudowords is a strong predictor of reading ability, a result consistent with the findings of the Pittsburgh research. However, like Ehri and Wilce (1983), de Soto and de Soto found differences between achieving and nonchieving readers in picture naming.

It should be noted that in the four studies just mentioned, Perfetti et al.'s skilled readers were at the 78th percentile of reading skill and Stanovich's skilled readers were formed on the basis of a median split of a classroom, wheras Ehri and Wilce's skilled readers were at 90th percentile and de Soto's less skilled readers were about two years below reading grade level. Besides, both the Perfetti et al. and Stanovich studies employed a discrete-trial procedure but De Soto used a continuous-list procedure. The lack of agreement among these four studies, therefore, may be due to subject differences and/or differences of experimental procedure. Regardless of the different findings on processing nonalphabetic stimuli, all four studies demonstrated that rapid word identification is one skill most clearly distinguishing skilled from less skilled readers.

In a comprehensive, multitask study, Curtis (1980) investigated performances of second, third, and fifth graders on various tasks including naming letters, words, and pseudowords, matching dots, letters, words, and pseudowords, short-term memory recall, listening comprehension, and reading comprehension. Curtis found that listening comprehension contributed unique variance to the reading comprehension measure. Also, naming words and psuedowords were best discriminators of skilled and less skilled readers. The results indicated that oral language processing and decoding factors are important ability determinants throughout the period between second and fifth grade.

Haines and Leong (1983) employed a vocalization task and a lexical decision task to examine the relative advantages of visual and phonological processing in readers of fourth, sixth, and eighth grades. The two tasks produced similar results reflecting the superior performance in higher grades and in skilled readers in terms of both speed and accuracy. In addition, the analysis of the performance on predictable, unpredictable, and pseudowords indicated that both direct visual access and phonological coding were used, but less skilled readers tended to make greater use and had more difficulty with the phonological coding route. Haines and Leong concluded that their findings were in line with those of the Pittsburgh research showing that less skilled readers are less efficient in decoding, especially in using a phonological strategy to process words.

The recent work of Manis (1985) also leads to a similar conclusion. He examined the acquisition of word recognition skill in normal and disabled fifth- and sixth-grade readers. The normal readers were those at or above reading grade level whereas disabled readers were two or more years below grade level. They were required to learn the meaning and pronunciation of unfamiliar words before performing a pronunciation task and a delayed pronunciation task. Manis found that even after three sessions of practice, disabled readers were slower than normal readers in pronouncing unfamiliar words. Besides, performance by both groups on the delayed pronounciation task revealed that the differences in vocalization speed were due to decoding rather than response excecution processes. Summarizing the results, Manis concluded that the deficient word naming performances of disabled readers in all conditions pointed to phonological coding and retrieval deficits as major sources of reading difficulties.

The relationship between word identification skill and reading ability is not only evident in elementary school readers but also holds for adolescents as well as adults. Frederiksen (1978, 1981), Mason (1978), Stanovich and Bauer (1978), Butler and Hains (1979), Jackson and McClelland (1979), and Hammond (1984) are some researchers who investigated the issue using high school or college students as subjects.

Research on high school readers has been done by Frederiksen (1978, 1981). The subjects for his studies were high shool students divided into four levels on the basis of the scores on the Nelson-Denny reading test. Tasks were designed to tap perceptual, decoding, and lexical components of reading. It was observed that high ability readers were superior in identifying letters in strings and faster at naming words and pseudowords. The results reflected that letter activation and decoding are two major ability factors among high school readers.

Using college students as subjects, Mason (1978) found that, except for high frequency words, less skilled readers made more errors and were slower than skilled readers in decoding regular and exception words. Moreover, less skilled readers were most disadvantaged in decoding nonwords, a task which requires phonological coding. From the results Mason argued that even in adults with a great deal of reading practice, reading comprehension cannot be separated from rapid and accurate word recognition.

Using correlational analyses, Stanovich and Bauer (1978) found that silent reading time as a measure of reading ability was correlated with speed measures from a naming task for a group of college students. A significant correlation was obtained between silent reading time and the naming time of irregular words ($r=.44$, $p<.05$). Also, silent reading time was highly correlated with the difference score between naming irregular and regular words ($r=.53$, $p<.025$). These correlational results suggested that better readers are faster at naming irregular words and appear to rely more on direct visual access. Stanovich and Bauer, however, noted that silent reading time is just a crude measure of reading ability and conclusions based on this measure must be tentative.

Employing vocabulary as a measure of reading ability, Butler and Hains (1979) observed that college students of high vocabulary had faster decoding speeds than did low vocabulary students. This study also provided a tentative suggestion that adult reading ability is related to word decoding.

The study of Jackson and McClelland (1979) is also noteworthy for understanding adult reading ability. They defined reading ability by a measure of effective reading speed which takes both accuracy and speed into account. In their study, college subjects were required to perform a number of reaction-time tasks and a listening comprehension task. Jackson and McClelland found that listening comprehension and letter matching were the two best predictors of reading effectiveness. Thus, in terms of word recognition subprocesses, it appears that access of letter codes is an important factor in adult reading ability.

Using both children (aged 10 to 12) and college students as subjects, Briggs and Underwoods (1982) examined phonological coding in good and poor readers. The researchers employed a picture-word interference task and a vocalization task. While the pattern of results from both children and adults failed to show differences in phonological coding ability between good and poor readers, the study demonstrated that poor readers, both children and adults, were significantly slower to name words and nonwords than good readers, a finding which is consistent with most other studies.

Whereas decoding factors appear to be less important in Jackson and McClelland's (1979) study, recent research by Hammond (1984, cited in Perfetti, 1985, pp.164-165) provided further clarifications on this point. In addition to perform a letter matching task like that in the Jackson and McClelland study, Hammond's college subjects also performed word and pseudoword naming tasks. Hammond observed that vocalization speed significantly differentiated high-ability readers from low-ability readers. Furthermore, the correlation between naming latency and reading ability remained significant even after controlling for correlation between letter matching and reading ability. Therefore, it seems that when more demanding access tasks are used, there is a decoding factor important in adult reading ability.

While the aforementioned studies of children as well as adults demonstrated the important relationship between word recognition ability and reading fluency, whether word recognition skill is a cause or a consequence of fluent reading cannot, at least not directly, be determined. A longitudinal study by Lesgold and Resnick (1982; Lesgold, Resnick, & Hammond, 1985), however, has served to untangle the relationship. The investigators studied multiple reading skills of several cohorts of children in different instructional programs through the first three years of the primary grades. The sample of children was divided into three ability groups (high, medium, and low reading skill) on the basis of second and third grade reading comprehension scores. At each test point several tasks including word vocalization, semantic judgment, and oral reading speed were given to each child. Through path analysis Lesgold and Resnick found that there were strong causal paths between each speed variable and a subsequent comprehension variable, but no paths of any weight from comprehension to a subsequent speed measure. These results confirmed the findings of previous studies that rapid word processing is a crucial component of reading comprehension. More important, Lesgold and Resnick suggested that rapid word recognition is a cause of more adequate reading skill, and not vice versa. More up-dated data of this study was recently presented in a paper by Lesgold, Resnick, and Hammond (1985). Even when different approaches of analysis were employed, the patterns of results remained the same showing that word recognition is a cause rather than a result of reading proficiency.

Taken as a whole, the studies reviewed in this section have all pointed to the repeated finding that skilled readers are more accurate and much faster at identifying context-free printed words than are less skilled readers at elementary stages as well as at later stages. In particular, differences between reader ability groups in word processing efficiency increase as a function of word frequency and word length. While skilled readers' advantage in accuracy may be restricted to low frequency words, their superiority in decoding speed is general and increases for low frequency words, pseudowords, and for longer words. Moreover, the longitudinal study by Lesgold and Resnick (1982; Lesgold, Resnick, & Hammond, 1985) has provided evidence of a causal link between word identification speed and comprehension ability. It can be concluded that the relationship between word recognition skill and reading ability is well documented. A related issue concerning readers' ability to use context in word recognition will be discussed in the following section.

2.1.2.4 Studies of word recognition in context

It has consistently been shown that less skilled readers are deficient in identifying words in isolation. The question that remains is whether or not less skilled readers are also deficient in identifying words in context. Two major research teams, the Pittsburgh group, and Stanovich and his associates, among others, have dealt with this issue.

Perfetti, Goldman, and Hogaboam (1979) of the Pittsburgh team compared word recognition latencies in discourse context and in isolation for groups of skilled and less skilled fifth-grade readers. Across the three experiments, discourse context, presented either aurally or visually, reduced vocalization latencies for less skilled as well as skilled readers. The size of the context effect was over 200 milliseconds for less skilled readers but less that 100 milliseconds for skilled readers. The results demonstrated the ability of less skilled readers and skilled readers to make use of story context in identifying words. Indeed, less skilled readers tended to take more advantage of relevant context than did skilled readers. The three experiments led to the same evidence that less skilled readers benefited from discourse context as much as, if not more than, skilled readers in identifying words. The researchers therefore concluded that the use of context in identifying words may not be a major source of reading difficulty.

Perfetti and Roth (1981) reported several experiments related to the issue. In one experiment third- and fourth-grade skilled and less skilled readers were required to identify words in three types of sentence context -- predictable, unpredictable, and anomalous. For the fourth graders, while both ability groups identified words faster in predictable contexts, only less skilled readers were slower in anomalous contexts. For third-grade readers, however, anomalous contexts displayed a similar inhibition effect on both ability groups. The results were interpreted as indicating that at least older skilled readers processed words with little context effect and less skilled readers were more dependent on context. In two other experiments with degraded inputs, subjects were asked to read a story and identify words in different levels of degradation. Perfetti and Roth found that skilled readers were less dependent on context and less affected by degrading. Nevertheless, skilled readers acted more like less skilled readers when the level of degradation increased. For example, at 21% degrading, skilled readers performed the same as less skilled readers without degrading. Summarizing the results, Perfetti and Roth suggested that less skilled readers, at the level of word recognition, are adequate users of contexts. They conjectured that less skilled readers are more affected by context because of their slower basic word-identification rate. Analogously, skilled readers can be just influenced by context in identifying degrading words, a situation when their basic word-identification rate are slowed down.

Stanovich and his associates have worked extensively with paradigms similar to those of the Pittsburgh group and produced highly convergent results. Using a sentence priming paradigm, West and Stanovich (1978) examined the performance patterns of fourth-grade, sixth-grade, and adult subjects on three contextual conditions -- congruous, neutral, and incongruous. They observed that older readers displayed less context effects than younger readers and that there was a significant negative correlation between the degree of context facilitation and the scores on the reading subtest of the Wide Range Achievement Test. The results indicated that younger and poorer readers make greater use of context in word recognition.

In a longitudinal study of second-grade children, Stanovich, West, and Feeman (1981) reported similar findings to those found in the West and Stanovich (1978) study. Employing the same paradigm, the researchers observed that contextual effects decreased with development during the school year. Moreover, the results concerning skilled and less skilled readers of the same age resembled the developmental trends. The correlations between overall context effect and three measures of reading ability (the reading subtest of the Wide Range Achievement Test, the reading subtest of the Standford Achievement Test, and paragraph reading time) were in the direction indicating that greater context effects were correlated with poorer reading ability.

Using a different paradigm in which responses to text alternation were observed, Schwartz and Stanovich (1981) also found similar patterns of context effect. Third- and fourth-grade good and poor readers read stories containing altered words which were anomalous to the text. They were instructed to read for understanding or for accuracy. The investigators found that both reader groups were able to conform to task demand for contextually appropriate reading responses. Nevertheless, poor readers were less able to suspend context information when accurate reading was required. The results showed that poor readers were at least as sensitive as good readers to contextual information.

More recently, Stanovich, Cunningham, and Feeman (1984) reported a longitudinal study of first-grade children. In the fall and spring of the school year, the investigators assessed the speed and accruacy with which the children read words in and out of context by having them read coherent story parapraphs and lists of random words. They found that both skilled and less skilled readers identified words more efficiently in coherent paragraphs than in random lists. In addition, both reader groups displayed a developmental decrease of context effect. More important, by comparing the random word recognition efficiency of the two groups, the researchers found that less skilled and skilled readers received similar context facilitation from coherent paragraphs when they were at similar levels of context-free word recognition skill. From the results, Stanovich et al. argued that when context is of their reading level, less skilled readers do make use of context. Their poorer performance on relatively difficult materials is due to poor decoding skill rather than to failure to use contextual information.

In a recent paper Stanovich (1984) reviewed some of the highlights of their research program. Relating the overall findings to his interactive-compensatory model of reading, Stanovich concluded that less skilled readers do not seem less likely to use context to facilitate word recognition provided that reading materials are within their capability. In his view, it is not contextual failures at the word recognition level but difficulty with graphic-phonemic analysis of words that characterizes the poor reader. Nevertheless, Stanovich emphasized that it is important to make the critical distinction between contextual facilitation of word identification and contextual facilitation of comprehension. While less skilled readers make use of context to facilitate word identification, contended Stanovich, their cognitive resources available to text-level processing are depleted and this eventually leads to poorer comprehension.

Results of other studies have also pointed to the evidence that less skilled readers are more influenced by context in identifying words. For example, Samuels, Begy, and Chen (1975-76), employing a tachistoscopic recognition task, reported data showing that poor fourth-grade readers exhibited greater a single word context effect than good readers of the same grade.

Using a sentence context paradigm, Juel (1980) also oberved a greater context effect for less skilled readers. The researcher tested second- and third-grade readers to read words under conditions of isolation, poor sentence context, and moderate sentence context. Results indicated that low ability readers benefited considerably from context for all word types, whereas high ability readers demonstrated little benefit from context except on low frequency, hard decodable words.

Using both single-word and sentence priming procedures, Merrill, Sperber, and McCauley (1980) found that the magnitude of context effects on word processing was almost identical for good and poor fifth-grade readers.

Recently, Simpson, Lorsbach, and Whitehouse (1983) examined the performance of third and sixth graders on a single word priming task. Like other studies, data showed that poor readers displayed greater benefit from context than good readers. The authors suggested that the results were consistent with Stanovich's interactive-compensatory model indicating that contextual factors may compensate for slow word decoding in poor readers.

Taken together, evidence supporting the notion that less skilled readers are not less able than skilled readers to make use of contexts in identifying words comes from studies using different research paradigms. As reviewed in this section, the results of studies of single-word priming (Merrill, Sperber, & McCauley, 1980; Samuels, Begy, & Chen, 1975-76; Simpson, Lorsbach, & Whitehouse, 1980), sentence priming (Juel, 1980; Merrill, Sperber, & McCauley, 1980; Perfetti & Roth, 1981; Stanovich, West, & Feeman, 1981; West & Stanovich, 1978), paragraph priming (Perfetti, Goldman, & Hogaboam, 1979; Stanovich, Cunningham, & Feeman, 1984), and responses to text alternations (Schwartz & Stanovich, 1981) have all pointed to the conclusion that use of context in identifying words appears not to be a key factor differentiating skilled from less skilled readers.

2.1.2.5 Summary of empirical research

Findings of eye movement research have demonstrated the central importance of lexical access in the reading process. Studies concerning word recognition automaticity and word recognition speed have all pointed to the repeated finding that accurate, automatic, and rapid word recognition is a crucial factor distinguishing skilled from less skilled readers at early and even later stages of reading skill development. Specifically, several studies have indicated that word recognition inefficiency may be a result of the deficient phonological coding processes of the less skilled reader. On the other hand, studies of word recognition in context have failed to show that less skilled readers are deficient in using context to facilitate word recognition. While further research is surely needed for determining the exact sources of ability differences in word recognition, from the available literature it seems clear that the skilled reader is the one who identifies words automatically and rapidly whether by direct visual access or by phonological recoding. In short, the bulk of relevant research reviewed previously appears to support the position that context-free word recognition is an important determinant of reading fluency.

While the relationship between word recognition and reading ability is well documented in the reading literature of English, it is an issue rarely explored with Chinese readers. The following part will review relevant literature of the Chinese language and reading research.

2.2 Theoretical and Empirical Issues in Reading Chinese

2.2.1 Theoretical issues in reading Chinese

In order to examine the relationship between word recognition and reading ability in Chinese readers, characteristics of the Chinese language and orthography will first be described. Specific task demands in reading Chinese will also be identified. With these analyses in view, important contrasts as well as similarities between Chinese and English as writing systems will then be discussed.

2.2.1.1 Characteristics of the Chinese system

The Chinese system is said to be both 'complex' and 'simple' (Wang, 1973). Such descriptions are not paradoxical. On the one hand, the writing system of Chinese, which involves thousands of unique characters, can be described as complex. On the other hand, the language has virturally no inflections for its verbs and nouns and is therefore structually simple.

According to Leong (1973, 1978), Chinese as a logographic orthography is best characterized as monosyllabic, isolating, and analytic. First, Chinese characters essentially map onto speech at the level of morphemes. Each character represents a morpheme and each morpheme is in fact a syllable. Hence, each Chinese character is a one-syllable morpheme. This monosyllabism represents one distinctive feature of the Chinese orthography. Second, in contrast to inflectional languages, Chinese is isolating in nature in that the Chinese character remains a constant shape in spite of syntactical changes. Third, Chinese is analytic because there are few bound forms in the language. In this sense, Chinese is different from synthetical languages such as Latin where bound forms are frequently used.

On analysing the sounds of the language, it is noted that every Chinese character has a distinguishing pitch pattern which is called the 'tone' of the character. In Mandarin there are four basic tones whereas there is a total of nine tones in Cantonese. In English, variation in tone does not change the meaning of the word being spoken but conveys different moods. In Chinese, however, changing tone has much the same effect on meaning of character as changing a vowel or a consonant. Wang (1973) used examples in Mandarin to illustrate the point: 1/ *mā* (媽) with a level tone means 'mother'; 2/ *má* (蔴) with a rising tone means 'hemp'; 3/ *mǎ* (馬) with a dipping tone means 'horse'; and 4/ *má* (罵) with a falling tone means 'to scold'. When the vowel is changed from *a* to *i* with a falling tone, we get *mì* (蜜) which means 'honey'. Also, when the consonant is changed from *m* to *p* we get *pà* (怕) which means 'fear'. It can be seen that in Chinese changing the tone alters the meaning as much as changing a vowel or a consonant. The differential use of tones thus constitutes another main feature of the Chinese language.

Speaking in terms of character formations, Chinese characters are structurally composed in a symmetrical and balanced way. According to Leong (1973), Chinese characters usually take either one of the five major forms: 1/ characters occupying the full square as in 日 'sun'; 2/ characters balanced vertically as in 門 'door'; 3/ characters in a tripartite vertical shape as in 淋 'watering'; 4/ characters balanced horizontally as in 早 'early'; and 5/ characters balanced three-ways as in 森 'forest'. More specifically, strokes in each character can be grouped into four broad groups according to the directionality of the stroke. Also, the sequence of strokes in a character is always fixed: from top to bottom and from left to right. These analyses have led Leong to argue against the American linguist Halle's description of Chinese characters as arbitrary symbols. In Leong's (1973) view, such a description "loses sight of the degree of orderliness and progression" (p.388) in Chinese characters.

Chinese characters are by no means arbitrary symbols, furthermore, because there are rules to classify characters into groups. Generally speaking, there are two principles of categorizing characters (Wang, 1981). One principle is to group characters according to the way the character is formed. By this way, Chinese characters can be grouped into six categories (Leong, 1973; Taylor and Taylor, 1983; Wang, 1981). First, pictographs (象形字) are characters which have iconic relations to the objects they represent. For example, 日 'sun' is an icon of ⊙, and 月 'moon' an icon of ☽. Second, simple ideographs (指示字) express ideas which the characters are designed to convey. Examples are 上 'up' and 下 'down'. Third, compound ideographs (會意字) contain two or more pictographs or ideographs to suggest an idea. For instance, the combination of two pictographs 日 'sun' and 月 'moon' means 明 'bright'. Fourth, loan characters (假借字) are those characters borrowed for new characters based on the identity of sound. For example, the ancient character 來 'wheat' was borrowed for the character 來 'come' because the two were homophones in Archaic Chinese. Fifth, phonetic compounds (形聲字) are made up of two or more components, usually a meaning-cuing signific or radical, and a sound-cuing phonetic. For example, the character 燈 'lamp' consists of the radical 火 'fire' and the phonetic 登. Finally, analogous characters (轉注字) are new characters derived from old ones where they are similar in meaning but do not have the same sound. This category, according to Taylor and Taylor (1983), is not clearly defined and applies to only a small number of characters. Altogether, the category of phonetic compounds turns out to be the most numerous and important category. Actually, Leong (1973) estimates 80% of characters falling within the phonetic compound category while Wang (1981) estimates that almost 9% of characters fall into this category.

Another principle of grouping characters is to classify characters in terms of radicals.[3] Radicals are used to cue meanings of characters. For instance, the 'water' radical 水 (written in the form of 氵 or 氺 as a radical in a character) referring to something liquid or watery, and the 'heart' radical 心 (written in the forms of 忄 or ⺗ as a radical in a character) denoting emotions or thoughts. Whereas English words are arranged according to alphabetical orders in dictionaries, Chinese characters are arranged according to their radicals and under each radical according to the number of strokes.

Putting together the two principles of character classification, some characteristics of Chinese characters are manifested. First, the radicals which cue the meanings of characters are unique properties of the Chinese orthography. Second, given that the great majority of Chinese characters are phonetic compounds, the phonetics which cue the sounds of characters are also distinctive constituents of the Chinese writing system. In this sense, Chinese orthography is not a pure logographic writing system. Indeed, most Chinese characters have a composite function and may best be described as morpho-syllabic (Wang & Tzeng, 1983).

While a character is the smallest morphemic unit in Chinese, most modern Chinese words are composed of the combination of two or more characters. A linguistic or syntactic word is "the smallest immediate constituent unit of segmental sentences" (Leong, 1978, p.162). For instance, 'school' in Chinese is made up of two characters 學校, which literally means learning-building, and is read as two distinct syllables. Also, a word like 'library' has three characters in Chinese written as 圖書館, literally picture-book-hall, and is read as three distinct syllables. Accordingly, the grapheme-sound mapping in

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[3] Traditionally, there are 214 radicals. Now in Mainland China, character simplification is part of the writing reform. The set of radicals has been reduced to 187, according to Wang (1981), or 189, according to Taylor and Taylor (1983).

Chinese words is perceptually discrete.

Regarding sentence formation, the basic sentence in Chinese, as in English, has a clear word order of subject-verb-object. Because of the analytic and isolating nature of the Chinese language, Chinese writing has essentially no morphological inflections and Chinese characters remain the same in spite of syntactical changes. For example, sentences of 'I love you' and 'you love me' in Chinese are written as ' 我愛你 ' and ' 你愛你 ' respectively. The same character 我 is used to denote 'I' as well as 'me'. That is, the character 我 remains the same no matter it is functioned as a subject or an object in a sentence (S. F. Liu, 1978). Besides, many grammatical marking elements are omitted in Chinese writing (Tzeng & Hung, 1981). An English sentence such as 'She goes to school', written in Chinese '她去學校 ' literally means 'She go school'. Furthermore, Chinese characters are capable of acquiring different kinds of grammatical functions according to the characters used in conjunction with them and the positions they occupy in the sentence (Leong, 1973; S. F. Liu, 1978). A character used as a noun may also be used as a verb, an adjective, and even asan adverb. For example, the same character 流 may function as a noun 'river' as in 河流 , as a verb 'to flow' as in 水流 , and as an adjective 'popular' as in 流行 (Leong, 1978). The grammatical flexibility of Chinese characters thus allows for a high degree of possibilities for combinations of unit word forms in the language. In short, the basic Chinese grammar depends on word order; it is the relative position of the characters in the sentence determining their roles and thereby giving meaning to the sentence.

To sum up, the Chinese writing system has several characteristics distinct from other languages and orthographies. First, the Chinese languages is monosyllabic, isolating, analytic, and tonal in nature. The structure of the smallest functional unit -- character -- seems to be complex in appearance, but most of the characters are formed in a symmetrical and balanced way reflecting orderliness and progression. In addition, over 80% of the characters are composed of a radical and a phonetic which may provide some information on their meanings and pronunciations. With respect to word formation, most Chinese words are made up of two or more characters and the grapheme-sound mapping in Chinese words is perceptually discrete. Chinese characters are virtually non-inflective; word order is the basic grammatical rule for formulating sentences.

These are the major features of the Chinese language and orthography. How do these characteristics constitute specific linguistic task demands in reading Chinese?

2.2.1.2 Task demands in learning to read Chinese

On analysing the task of learning to read in different languages, Downing and Leong (1982) have pointed out that the initial task in all languages is to learn how written symbols represent spoken language. As Chinese characters essentially map onto the language at the morphemic level, the learner's task is primarily to associate the characters of the Chinese orthography with the morphemes of the Chinese language. In addition, because each morpheme is in fact a syllable, learning to read in Chinese also means learning to relate each spoken syllable to a particular character of a designated meaning. Furthermore, Chinese characters are virtually non-inflective. Chinese children are able to learn characters independent of syntactical structure. The one character - one morpheme - one syllable characteristic of the Chinese system and the non-inflective nature of Chinese characters thus provides a quite concrete learning situation for beginning readers.

Nonetheless, the one-to-one grapheme-morpheme relationship between Chinese orthography and language inevitably requires more than thousands of distinctive characters to represent all imaginable linguistic morphemes. As Leong (1973) has noted, the authoritative Kangshi dictionary (康熙字典) of the eighteenth century contains about 42,000 to 48,000 characters, depending on the edition, with 6,000 to 7,000 characters in active use. Leong (1973) estimated that the minimum number of characters to be acquired as adequate for daily use is about 3,500. It must be remembered that Chinese words are multisyllabic in nature and are usually made up of two or more characters. Hence, the size of the fundamental vocabulary in terms of Chinese words must be many more than the minimum number of characters. For example, according to a study done in Taiwan, the number of commonly used characters is about 4,500, but the number of commonly used words is about 16,000 (Liu, Chuang, & Wang, 1975).

Not only is the number of characters needed for literacy huge, but the complexity of characters is also regarded as overloading the task of memorization in learning to read in Chinese. The complexity of a character can be measured by the number of strokes. A stroke is a dot or a line "that is completed every time the pen leaves the paper" (Wang, 1973, p.53). The number of strokes in a character can arrange from 1 to over 30 strokes.

The large number and the complex appearance of characters have led many foreign and even Chinese scholars (e.g. Halle, 1968, quoted in Leong, 1973; Tzeng & Hung, 1980) to emphasize the role of visual discrimination and rote memory in learning to read Chinese. While it is commonly agreed that visual discrimination is an important task in learning Chinese characters, further analysis indicates that the much-mentioned reliance on rote memory may have been overstated.

Although each character has to be learned, there are rules and strategies in encoding the symbols (Leong, 1973). First, Chinese character, as have been noted before, are usually composed in forms which show symmetry and balance. Strokes in each character can also be broken down into groups according to their directionality. Besides, the number and order of strokes in a character is fixed. Being aware of these characteristics of a character, namely the internal structure, the nature and directionality of the strokes, may help learning Chinese characters.

Second, the complexity of Chinese characters does not necessarily impose more task demands on learning the characters. According to Leong's (1973) analysis, the average number of strokes of most commonly used characters is around 11 to 12 with a standard deviation of about 4. He contended that this mean stroke number "is probably the limen for optimal visual cues in the perception of Chinese characters"(p.389). It follows that extremely simple characters may provide less visual cues and may thereby lead to some cognitive confusions. Actually, Leong's (1972) study of the written vocabulary of Hong Kong children indicated that it is not definitely easier to learn and use apparently simple characters. Taylor and Taylor (1983) also argued for the importance of the Gestalt pattern, rather than the number of strokes, in learning Chinese characters.

Third, and perhaps the most important point is that understanding of intra-character semantic-phonetic components may greatly help learning Chinese characters. Every Chinese character contains a radical which cues the meaning of the character. Although there are 214 traditional radicals, Leong (1973) cited Herdan's (1962) findings that 17 commonly used radicals (8% of the 214 radicals) account for over 50% of the 8,711 characters in Mathew's dictionary. These high frequency radicals are themselves pictographs or simple ideographs denoting something related to nature (e.g. 水 'water', 土 'earth'), flora (e.g. 草 'grass', 木 'wood'), fauna (e.g. 虫 'insect'), or human (e.g. 手 'hand', 人 'human'). Thus, knowing the meanings of the commonly used radicals enables the reader to generate meanings of many compound characters. Moreover, given that the great majority of Chinese characters are phonetic compounds, the reader can also obtain phonetic clues of a character by analysing its phonetic component. The high ratio of phonetic compounds in Chinese characters has led Wang (1981) to argue against the statement that the Chinese script is nonphonetic. It should be noted that the phonetics are not always accurate clues to pronunciation due to language evolution over time and in that tonal patterns are not included. Nonetheless, being aware of the phonetics at least provides some hints of the phonetic aspect of Chinese characters. All in all, the semantic-phonetic elements constitute the basic units in the Chinese language that are critical to learning to read. Wang (1981) even suggested that such a method upon which most Chinese characters are based - that of presenting clues simultaneously to both the sound and the meaning of the word - may turn out to be the most rational foundation for optimal orthography.

Along this line of analysis, it can be seen that counting the number of strokes in a character is one of the many ways of defining the complexity of a character. Other aspects such as the structure, the imageability, and the semantic-phonetic components of a character may also need to be taken into account when defining the complexity of a character.

In short, the primary task in learning to read Chinese is to relate Chinese characters to the morphemes of the language. As a huge number of characters representing different morphemes have to be learned, it is generally assumed that literacy in Chinese may require tremendous task demands on both visual discrimination and memorization. However, since there are rules and strategies in encoding Chinese characters that may help reduce the burden of memorization, the often-mentioned reliance on rote memory appears to be overstated. Being aware of the internal structure, the nature and directionality of the strokes in each character, and understanding the intra-character semantic-phonetic components are the major strategies that may help learning to read in Chinese. In view of the characteristics of the Chinese language and the task demands imposed by the orthographic structure of the Chinese script on reading, it is now possible to compare and contrast Chinese and English as two writing systems.

2.2.1.3 Chinese and English as writing systems

In appearance, Chinese and English are two disparating writing systems in that they represent two different orthographic rules for mapping script onto speech. Chinese characters are logographic or ideographic symbols mapping onto speech at the morphemic level. Each character is a morpheme and also a syllable. In contrast, English is an alphabetic system in which the embedded grapheme-speech relationship is best characterized as a morphophonemic representation (Tzeng & Hung, 1981). It means that in English, the written symbols map onto speech at the level of phonemes where the lexical root of each word is simultaneously taken into consideration. Speaking in terms of syllabication, because of the monosyllabic nature of Chinese characters, spacing in Chinese script is discreted syllable by syllable and therefore has a one-to-one correspondence with the syllabic boundaries of the speech. On the contrary, spaces in English script are largely determined on the basis of words where grapheme-sound relationship is continuous. Still another important contrast between Chinese and English is that English words have different forms reflecting syntactical structures, but Chinese characters remain the same regardless of syntactical changes. Within this framework, Tzeng and Hung (1981) contended that the script-speech relationship is more abstract in English than that in Chinese. As a result, the initial task in learning to read appears to be less complex in Chinese than in English. Further examination, however, demonstrates that there are linguistic similarities between Chinese and English.

Attempts have been made by Wang (1973) and Leong (1973, 1978) to show the isomorphy of Chinese with English.

Leong (1978) argued that individual Chinese characters are counterparts to syllables in English. Being the smallest functional units, Chinese characters are the basis of forming multisyllabic words. A character thus corresponds to a syllable in English. Moreover, Leong (1978) cited Wang (1973) to illustrate that the information content of the strokes in a character is comparable to that of the letters in an English word. There are approximately 20 stroke types, according to Wang (1973), or 18, according to Leong (1973). The distinct stroke types are parallels to the 26 letters of the English alphabet.

More important, while studies in English have shown that there is an invariant spelling-to-sound relationship embedded in the English orthography, Leong (1973) found that there is also orthographic invariance inherent in the basic structure of Chinese characters. The phonetic and the radical, which constitute the critical components in learning to read in Chinese, represent the invariant spelling-to-morpheme and even to sound units within each character. Particularly, as noted before, 8% of the 214 radicals account for over 50% of the Chinese characters. The high frequency of such a small number of radicals, argued Leong (1973), "must necessarily relate to morphological and spelling constraints that are analogous to English"(p.392). As Leong (1973) mentioned in his article, such a view is supported by empirical evidence offered by Herdan (1962) showing that there exist notable similar measures of redundancy in the binary coding of English letters and the system of coding by stroke number in Chinese. It is this linguistic correpsondence that underlies the isomorphy of the two apparently disparating writing systems. With these analyses in view, Leong (1973) suggested that "as with English, the child learning Chinese should be encouraged and guided to develop reading habits that utilize all the types of constraint present in the stimulus and to note the contrastive elements in the characters. This ability to recognize and to discriminate graphic shapes before decoding them and to find a phonemic correspondence is a prerequisite in reading" (pp.394-395). In other words, it is important to raise the linguistic awareness of the child to meet the task demands imposed by the orthographic structure of the script on reading.

2.2.1.4 Summary of theoretical issues

The Chinese language is best characterized as tonal, monosyllabic, isolating, and analytic. Each Chinese character is a morpheme as well as a syllable with non-inflective nature. Most Chinese characters are composed of a radical and a phonetic which may provide some information on their meaning and pronunciation. Modern Chinese words are multisyllabic in nature and word order is the basic grammatical rule for formulating sentences. All these characteristics constitute specific task demands in reading Chinese.

Comparatively speaking, owing to the nature of Chinese characters, the initial task in learning to read in Chinese seems less complex than that in English. There is, however, linguistic correspondence between the two writing systems that some of the psychological principles may be relevant across orthographic boundaries. Similar invariant orthographic structures are inherent in the two systems. Specifically, the distinctive characteristics of the radicals and the phonetics are comparable to letter groupings in the English morphophonemics. The linguistic awareness of the child - a knowledge of the nature of the language and an understanding of the reading task - therefore constitutes an important part in learning to read, whether in Chinese or English.

These theoretical analyses lead us to suggest that there might be similar psychological processes underlying reading in English and Chinese. As there is linguistic correspondence between the two linguistic codes, it is logically possible that word recognition may play a similar role in reading Chinese to that in English. Now we should search for an empirical support for such a postulation.

2.2.2 Empirical issues in reading Chinese

The investigation of the Chinese language as a field of study has a history of over thousand years. However, the study in tradition was often confined to the viewpoints of linguistic and cultural development. It was not until this century that researchers began to study the language from a psychological perspective. In search of an empirical support for the importance of word recognition in reading Chinese, a brief historical review of the psychological research on the Chinese language will first be presented. Reading disability research in Chinese children, though rarely been carried out, will then be reported. Finally, current related research issues in reading Chinese will be discussed.

2.2.2.1 A brief historical review

Historical reviews of the psychological studies of the Chinese language have been given by I. M. Liu (1978) and Kao (1982). Some major points that are derived from these reviews are provided here.

In his thorough review, Kao (1982) pointed out that the history of psychological research on the Chinese language can roughly be divided into two stages. The first stage from 1920s to 1950 was a period of research mainly concerning education and application issues. It was in the second stage from 1950s to 1980 that research paradigms of experimental psychology have evolved. Entering the 80s, cognitive psychology plays an important role in directing the research.

An early psychological study of the Chinese language was carried out by Tin-fung Liu in 1921 at Columbia University. Based on the results of his experiments of learning and memorizing Chinese characters, Liu found that the effect of character shape on its meaning acquisition is much greater than character sound. Liu's study demonstrated the importance of graphic information in learning an ideographic script such as Chinese.

Among researchers of the first period, Wei Ai's work has been regarded as most extensive and influential. Ai started his investigation of the Chinese language in 1923 and carried on research work for more than 20 years. His findings were summarized in his two books, *The psychology of reading: The question of the national language* (1948), and *The psychology of reading: The question of Chinese characters* (1949). Ai conducted studies investigating character learning, examining interest factors in children's reading, comparing oral and silent reading, assessing children's ability in silent reading, analysing composition errors, etc. From his results, Ai made suggestions for preparing elementary textbooks and for further studies.

Other major areas of research during this period included studies of daily vocabulary, comparing horizontal versus vertical arrangements of Chinese characters on speed of reading, and studies of calligraphic writing and so forth.

In brief, during the first three decades, psychological studies of the Chinese language focused on three major themes: learning, visual perception, and performance. Research methods included observations, surveys, assessments, and experiments. Most of the studies were aimed at educational and practical purposes. Consequently, few studies were directed to theory building and model construction.

The major characteristic of the second stage of research is thedevelopment of experimental psychology in studying Chinese. While educational and practical purposes have not been neglected, attempts have been made to theory building and model construction. Some main areas of research that have been developed during this stage are as follows.

Vocabulary study is still one main area of the ongoing research. First, studies on frequency of occurrence of Chinese characters and words have been active in Taiwan. Research on frequencies of Chinese characters used in elementary schools by Taiwan National Compilation Committee (1967) represents the first most extensive and systematic study in this area. In this study, 4,864 different Chinese characters and their frequency counts were obtained from a body of elementary natural-language text.

Another study by Liu, Chuang, and Wang (1975) focused on frequency counts of linguistic words instead of single characters. 40,032 different Chinese linguistic words and their frequency counts were collected from a sample of daily reading materials.

More recently, Cheng (1982a) presented a frequency analysis of 4,583 Chinese characters. The Cheng study was accomplished by transforming the frequency counts of linguistic words in Liu et al's (1975) study into those of Chinese characters.

In addition to studies of frequency, research on meaningfulness and imageability values of Chinese characters and words has also been carried out. For example, Liu and Chuang (1970) developed an index of associative meaningfulness for 1,200 Chinese characters. Chuang (1975) established norms of scaled imageability values for 200 Chinese words. A study by Huang and

Liu (1978) set up normative frequency counts, meaningfulness and imageability values for 239 Chinese words. All of these studies have produced a better data base for educational and psychological research.

Another area of research is concerned with perception of Chinese characters. Yeh and Liu (1972) found that recognition thresholds were related to meaningfulness and number of strokes of the characters, but not so much related to character shape and character formation.

Cheng (1982b) studied character- and word-superiority effects in perceiving Chinese characters. He found that a Chinese character was better perceived tachistoscopically when embedded in a word context than in a non-word context. Also, there were advantages of character over pseudocharacter, pseudocharacter over noncharacter in perceiving a constituent of a Chinese character. These results were in line with those of the English language studies. However, Cheng argued that, unlike English symbols, the advantage of pseudocharacter over noncharacter cannot be attributed to phonetic encoding or sequential redundancy among constituents in favour of pseudocharacter. Rather, the advantange may be attributed to positional redundancy among constituents in favour of pseudocharacters. Moreover, while the accuracy rate of character and word recognition were significantly related to the complexity but not to the frequency of presented characters, both character- and word- superiority effects were not sensitive to these two variables. From the results, Cheng suggested that analysis of constituents might be necessary for reading a Chinese character.

Huang (1984) tested the perceptual separability of characters in conditions of no context, word context, and sentence context, and in conditions of degradation and without degradation. He found that perceptual separability of characters and reading time were significantly higher in conditions of no context and degradation. Huang suggested that the results were consistent with McClelland and Rumelhart's interactive model of reading in English in that there were interactions of the bottom-up and the top-down processes even in reading Chinese.

A few studies examined paired-associate learning (PAL) of Chinese words. A study by Cheng and Chen (1976) assessed the effects of noun concreteness and presentation rate on paired-associate recall. The results showed that concrete nouns were better recalled than abstract nouns, and that recall difference between concrete and abstract nouns decreased as presentation rate decreased. Huang and Liu (1978) investigated the effects of frequency, meaningfulness, and imageability value on PAL of Chinese words. They found that there were significant imagery effect on all three sources of variation: stimulus units, response units, and interaction of the two units. Also, there were significant frequency effects on the latter two sources of variation but not on stimulus units. Huang and Liu concluded that while the overall results were in line with those of current English language studies, the idiosyncratic properties of Chinese words should further be studied.

In regard to Chinese reading comprehension, Lin and Cheng (1976) found that comprehension efficiency was greater when essays were with relevant headings versus without headings or with irrelevant headings. Also, Chen and Cheng (1976) reported that speed training, though resulting in faster reading, did not lead to better comprehension. By separating comprehension from the verification process, Liu (1984) observed that affirmative sentences were comprehended faster than negative sentences and that 2-proposition sentences were comprehended faster than compound sentences. From the results, Liu developed a model of Chinese sentence comprehension to explain and predict the comprehension of various types of sentences.

While the above studies are of value in understanding the psychological properties of the Chinese language, recent research using an information processing approach has more profound impact on future research of the Chinese language. These recent developments will be discussed in detail in a latter section.

Up to this point, the history of psychological studies of the Chinese language during the past 60 years has been reviewed. From a developmental perspective, there are several significant changes during the two stages of development. First, it has shifted from its first 30 years on teaching and application to become in-depth research on experimental psychology. Second, it has gradually changed from the study of classical learning theories to the study of perception, memory, information processing and the current research on cognitive psychology. Moreover, research methods like survey, observation and gross measures have been replaced by precise experimental design, the most updated statistical approach, and the use of modern instruments. Finally, the scope of research has been broadened from the examination of the unique psycholinguistic properties of the Chinese language to comparative studies among different languages reflecting international interest and endeavours. In sum, the research during the past 60 years has developed from the investigation of the Chinese language in particular to the exploration of human language behaviour as a universal cognitive activity.

2.2.2.2 Reading disability research in Chinese children

While reading disability has become a problem of concern in most Western countries, it has hardly drawn special attention in Chinese societies (i.e. The People's Republic of China, Taiwan, and Hong Kong). It was not until the last decade that psychologists and educators developed their study of reading disability in Chinese children (Kline & Lee, 1972; Kuo, 1981; Stevenson et al, 1982). Moreover, Chinese children with reading disability have been deemed very low in number (e.g. 2.91% in Kuo's study). It is proposed that the low prevalence of reading disability in Chinese children may be related to the structure of the Chinese orthography. While such an hypothesis is interesting, its validity remains to be established. In this section, the studies of reading disability in Chinese children will be examined, with related studies discussed. As there is no explicit definition of 'reading disability' available from the reading literature of Chinese, here the term is used in a broad sense referring to the broad group of children, of average or above average intelligence, experiencing varying degrees of reading difficulties.

Interesting enough, the idea that Chinese readers may be immune to the problem of reading disability has its origin in studies with non-Chinese children. A survey done by the Japanese child psychiatrist Makita (1968) reported extremely low incidence (0.98%) of reading disability in Japan amongst Japanese children. Since the Japanese orthography has two types of scripts - kana and kanji, (kanji literally means Chinese character), the rarity of reading disability may be attributable either to the relative ease of learning the syllabic kana script or the Chinese kanji script, or both. Although Makita pointed out that Japanese children tend to experience more difficulties with kanji script, the prevalent rarity of reading disability in Japan has led the psychiatrist to hypothesize that "the specificity of the used language is the most potent contribution in the formation of reading disability" (Makita, 1968, p.613). Another much-mentioned study is the one carried out by Rozin, Portsky, and Sotsky (1971). In their study, 8 Philadelphia disabled readers of second grade were taught to recognize 30 Chinese characters, to relate them to the English spoken words, and to arrange the characters into meaningful sentences. With 2.5 to 5.5 hours of Chinese tutoring, the subjects were successful in learning to read English represented by Chinese characters. In contrast, with the relatively same amount of English tutoring, little progress was made in reading English represented by English alphabets. Rozin et al. argued that the success of the program was partly due to the novelty of the Chinese orthography but largely due to the fact that Chinese characters map directly onto meaning whereas in English orthography the relation of symbols to meaning is mediated through the sound system.

In a similar way, Harrigan (1976) conducted a project with 7 Maine first graders who were having reading difficulties. The subjects were taught to read English represented by 8 to 15 Chinese characters. The results were quite in agreement with those of Rozin et al.. Harrigan reported that the subjects showed no inability to learn sign to sound when English words were represented by Chinese characters. However, there was no comparable gain in the ability to read English orthography. Harrigan contended that Chinese characters are cognitively processed differently from English words and constitute a less difficult task for learning to read.

While the results of the above studies were highly interesting, it should be pointed out that they have been criticized as having a number of shortcomings (Leong, 1978; Tzeng & Hung, 1981). First, for Makita's study, it has been commented that cultural factors such as different educational philosophies and practices, academic competitions, and parental attitudes should be taken into account when interpreting the results. More important, in a country like Japan where public image is highly emphasized, the reliability of the survey method, in which teachers' replies were the sole source of information, is questionable. Regarding the studies by Rozin et al and Harrigon, it should be noted that the number of subjects were 8 and 7 respectively. The small number of subjects casts doubt on the generalization ability of the studies. In addition, the Chinese characters taught to the American children were not well selected, not to mention the small number of characters included. Remember that the minimum number of characters required for a reader of Chinese is about 3,500. In view of these shortcomings, the validity of the findings of these studies is highly questionable.

Despite the above mentioned weaknesses, the notion that reading disability rarely exists in readers of Chinese originated from these studies has incidentally gained support from studies with Chinese children. The research conducted by Kline and Lee (1972) may be the first study investigating the problem of reading disability in Chinese children. In the Kline and Lee study, 277 Canadian Chinese children in Vancouver, who were simultaneously learning to read both Chinese and English, were given the Iota Reading Test in forms of English and of Chinese. Disability in reading Chinese was determined by scores on the Chinese Iota Test together with judgements by the Chinese language teachers. The results of this study demonstrated that there was evidence for reading disability in Chinese (19 %). However, the incidence of difficulty in Chinese dropped significantly at the end of grade three (6 %). The low incidence of reading disability among Chinese children after grade three was attributed to the multisensory training the children received in Chinese-language schools. On the whole, the findings of this study suggested that the problem of reading disability in Chinese children is not so serious as that in readers of English. However, methodological problems such as the equivalency and reliability of the English and Chinese versions of the Iota Reading Test cast doubt on the validity of this study.

In Taiwan, Kuo (1981) carried out a large scale survey of reading disability in Chinese children. A questionnaire was distributed to primary school teachers in the Taipei city area as well as to those in rural school districts. The results of the survey showed that only 2.91 percent of the target population were referred by their teachers as supsected reading disabled children. It was also found that the incidence decreased inversely with grade-level. The results were therefore in accord with the findings of Kline and Lee (1972) showing that the problem of reading disability among Chinese children may be rare. However, like Makita's study, cultural factors should be taken into consideration when interpreting the results. Moreover, this study was a crude survey just like the one done by Makita and its reliability was therefore questionable.

With respect to studies carried out in Mainland China, although no published research of reading disability is available from the People's Republic of China, a recent study by Zeng (1983a, 1983b) demonstrated the relative ease of learning and using Chinese characters.

In the People's Republic of China, the pinyin system -- an alphabetic form of writing using Roman phonetization with consistent grapheme-phoneme correspondence -- is used to assist in learning the pronunciations of Chinese characters. Children entering primary school are first taught written Chinese using pinyin. After the initial instruction of pinyin, characters are introduced. Consequently, a student in China learns written Chinese in two ways. Using pinyin, he learns the pronunciations of Chinese characters. Using traditional form of writing characters, he learns their meanings (S. F. Liu 1978).

In Zeng's (1983a, 1983b) study, a listening dictation test was given to first graders in three primary schools in Shanghai. The students were asked to write 30 Chinese characters and their corresponding forms in pinyin from dictation. The results showed that the students made more errors in writing pinyin than in writing characters. Zeng therefore argued that it is easier to learn Chinese in characters than to learn Chinese in an alphabetic pinyin system.

All the studies mentioned above advocated that reading disability is related to orthographic factors, and that learning to read in Chinese logographic script is easier than learning to read in English alphabetic script. However, most of these studies were confounded by various methodological problems. Interpretation of their results, therefore, must be made with extreme caution. Moreover, the results of a cross-cultural research carried out by Stevenson et al. (1982) demonstrated evidence against the findings of these just mentioned studies.

In Stevenson et al.'s (1982) study, a reading test was constructed in English, Japanese, and Chinese to assess reading ability of children in each country. Children included in the study were fifth graders from three cities: Minneapolis (the United States), Sendai (Japan), and Taipei (Taiwan). The reading test was constructed to include seven levels (kindergarten, grades one to five, and a grade six to adult level), with three parts (vocabulary, reading of text, and comprehension) at each level. Using the criterion that the reading disabled child is one who is reading at least two grade levels below his own grade, the data showed that approximately 3% of the American children, 8% of the Japanese children, and 2% of Chinese children were classified as reading disabled. Using another criterion that reading disability is low reading ability together with average or near-average IQ, the percentage of reading disabled children in the three countries was 6.3% in the United States, 5.4% in Japan, and 7.5% in Taiwan.

Hence, Stevenson et al. claimed that reading disability exist among Chinese, and Japanese, as well as among American children. In other words, the study demonstrated evidence against the hypothesis that orthography is the major factor determining the incidence of reading disability across cultures.

Taken together, it can be seen that only a paucity of research has been carried out on the topic of reading disability in readers of Chinese, and most of the studies were not well designed. While more research is needed before any conclusion can be reached, some current research issues, though not strictly directed to the problem of reading disability, has revealed interesting results that may shed light on the problem.

2.2.2.3 Current research issues in reading Chinese

Two current research approaches have attempted to reveal, from an information processing perspective, the fundamental properties of reading Chinese. One is concerned with the problem of cerebral lateralization effects and the other with the problem of coding processes.

As Tzeng, Hung, and Garro (1978) noted, "the term 'lateralization' refers to the specialization of the left or right hemisphere of the brain for difficult functions"(p.288). It is generally held that the left hemisphere is specialized for analytic and sequential functioning and the right hemisphere is superior in imagic and holistic functioning (Leong, 1982). As language (spoken as well as written) requires sequential and analytic processing, it has been observed that verbal material is usually processed by the left hemisphere, whereas visual-spatial material is processed by the right hemisphere.

One major research paradigm used to study the cerebral laterization functions for processing linguistic materials is the visual half-field experimental parardigm, in which verbal stimuli are tachistoscopically presented to either right or left visual-half field and recognition accuracy and latency are measured. As pointed out by Tzeng et al. (1978), the rationale behind the visual half-field experiment is:

> When a subject looks at a fixation point in the centre of a lighted square within a tachistoscope, each visual half-field

> projects onto the contra-lateral hemisphere.... If language is indeed processed in the left hemisphere, then verbal stimuli presented to the right visual field should take less time to respond than when the same materials are presented to the left visual field. The delay in reaction time is attibuted to the time it takes to transfer information from one hemisphere to another (pp. 292-293).

Most studies investigating the visual lateralization effects of language processing have employed English alphabetical materials as stimuli and the findings have often pointed to the right visual-half-field (hereafter VHF) superiority effect (Tzeng, Hung, & Garro, 1978). It is postulated that English words enjoy an right VHF advantage because the phonetic coding required for processing alphabetic materials is carried out in the left hemisphere. As reading Chinese characters is considered much more like a pattern recognition task which is presumablily carried out in the right hemisphere, Chinese characters may enjoy a left VHF advantage rather than a right VHF as do English words.

In one of his earlier studies, Hatta (1977) investigated recognition accuracy of high and low familiarity kanji in normal Japanese subjects. Left VHF (right hemisphere) advantage was observed for both types of kanji characters.

Following Hatta's (1977) study, Tzeng, Hung, and Garro (1978) conducted an experiment with Chinese subjects in which left VHF superiority was also found for both pictographic and phonetic Chinese characters. These two early studies demonstrated the superiority performance of the right hemisphere in recognition of logographic characters.

Later developments, however, have complicated the seemingly clear conclusion. Tzeng, Hung, Cotton, and Wang (1979) reported three experiments with Chinese subjects on visual lateralization effects in processing Chinese characters. The first experiment was the one reported earlier in Tzeng, Hung, and

Garro (1978) and the results basically replicated those of Hatta (1977) showing a left VHF advantage for processing single characters. The data of the second experiment, in which the stimuli were two-character words, however, showed a right VHF superiority. The results, therefore, suggested a left hemisphere dominance which was a complete reversal from that of the first experiment. In order to further clarify the issue, the researchers carried out a third experiment in which the subjects were requested to make a semantic decision on multiple-character terms. The results of this experiment, like those of the second one, showed a right VHF advantage. Tzeng et al. interpreted the seemingly conflicting results as reflecting the function-specific property of the two hemispheres. As the experimental task in the first experiment emphasized a holistic recognition of single characters and this task is better handled by the right hemisphere, it was reasonable to have results showing a right hemisphere dominance. In contrast, since the experimental tasks in the second and third experiments required sequential and analytic processing for semantic judgement and these tasks are better handled by the left hemisphere, it was not surprising that the data suggested a left hemisphere superiority. In consequence, Tzeng et al. concluded that the results of the three experiments altogether were compatible with the differential functional views of cerebral lateralization.

Similarly, in his later study Hatta (1981) reported results convergent to those of Tzeng, Hung, Cotton, and Wang (1979). Using Japanese college students as subjects, Hatta carried out three experiments in which the subjects were instructed to perform tasks of pattern matching, lexical decisions, and semantic comparsion of kanjis. The results showed a left VHF advantage in pattern matching, no left/right VHF difference in lexical decision, and a right VHF superiority in semantic comparsion. From the results Hatta contended that there are different stages of processing kanji. Processing demands are different from the stronger contribution of the right hemisphere in perceptual matching, to a balanced contribution of both hemispheres in lexical judgement, to the more left hemisphere dominance in semantic comparsion.

More recently, Leong, Wong, Wong, and Hiscock (1985) examined visual laterality effects in different levels of processing single Chinese characters. Chinese university students were asked to perform tasks of lexical decision, phonological identification, and semantic judgement. It was found that there was no left/right VHF difference in the lexical decision task but right VHF advantages in recognition accuracy in the later two tasks which required phonological or semantic processing. The researchers therefore argued that visual laterization effects for Chinese characters vary with task demands of orthographic, phonological, and semantic processing.

Based on the results of these studies, it seems clear that visual lateralization effects for Chinese characters appear to be task-specific rather than orthography-specific. In other words, while initial perceptual processing of Chinese characters is more like a pattern recognition task and the involvement of the right hemisphere is therefore greater, further linguistic analysis of Chinese characters which involves phonological and/or semantic components requires sequential and analytic processing and the contribution of the left hemisphere is consequently stronger. Recently, after an extensive review of research in this area, Tzeng and Hung (1984b) concluded that Chinese characters are in general processed in the left hemisphere and occasionally a right hemisphere advantage may be obtained but the effect is non-linguistic in nature. In short, when linguistic processing is required, lateralization effects for processing verbal materials often point to left hemisphere dominance, no matter whether the materials are in English or Chinese.

Another problem that has received much attention is concerned with coding pathways and processes in reading Chinese. Two specific questions have been raised. One question asks if there is greater visual involvement in processing Chinese characters. Another question centers on the necessity of phonetic recoding in reading Chinese.

As Chinese characters are essentially logographic symbols, it is assumed that greater perceptual demands may be involved in reading Chinese. The Stroop task, the research paradigm for investigating automatic word processing in English, has been employed by several researchers to explore the nature of processing demands in reading Chinese characters. Biederman and Tsao (1979) reported a comparative study in which Chinese subjects were asked to perform a Chinese-version Stroop colour-naming task, and American subjects, an English version. A greater interference effect for Chinese subjects than for American subjects was observed. The investigators attributed the difference to the possibility that there may be greater perceptual demands involved in reading Chinese than in English.

Following Biederman and Tsao's (1979) procedures, Fang, Tzeng, and Alva (1981) carried out a study investigating intra-language and inter-language effects in bilingual subjects. The researchers found that for Chinese-English bilingual subjects inter-language colour naming produced less interference effect than did intra-language colour naming. They suggested that as Chinese and English represent two different orthographies, switching from one to the other may enable the bilingual subjects to employ different processing strategies and as a result cause them to be released from the Stroop interference. In short, it appears that in processing Chinese, the configuration of a character plays an important role and greater perceptual demands are required.

Along this line of analysis, one might argue that more visual memory may also be involved in the processing of Chinese characters. Chen and Juola (1982) examined the effects of graphemic, phonemic, and semantic information on lexical coding and memory for Chinese logographs and English words. They conducted an experiment using a recognition memory task for Chinese and English words with separate subject groups of native speakers of the two languages. Subjects were instructed to choose one of a pair of test words that were graphemically, pheonemically, or semantically similar to a word on a previously studied list. They observed that the Chinese subjects responded most rapidly and accurately in the graphemic recognition task, while no significant performance difference was found in the three tasks for English subjects. The results therefore demonstrated different lexical coding and memory mechanisms for Chinese and English words. The researchers concluded that Chinese characters produce significantly more visual information in memory, whereas English words activate a more integrated code involving visual, phonological, and semantic information.

Recently, Fang and Tzeng (1984) compared the memory performance of native English speakers and native Chinese speakers. A series of nine items were presented auditorily or visually to the subjects in their native languages. The investigators found that both subject groups recalled last items better in auditory presentation. Nonetheless, whereas Chinese subjects recalled earlier items better in visual presentation than in auditory presentation, there was no difference between auditory and visual presentation for English readers. Moreover, Chinese subjects consistently performed better in visual presentation no matter whether they asked to recall the items in oral or written forms. In brief, the findings indicated that the processing of Chinese symbols involves more visual memory than does the processing of English script.

The greater involvement of visual memory in processing Chinese characters has also been demonstrated in the VHF experiments. As mentioned earlier, greater involvement of the right hemisphere has been observed in processing single logographs, indicating that visual coding is more critical in the initial task of processing Chinese characters. However, it has also been pointed out that in the deeper linguistic levels of analysis, both Chinese and English reading require the left hemisphere to handle sequential and analytic processing. In other words, the initial perceptual pathways may be different in reading Chinese and English scripts, but later stages of processing may require similar linguistic techniques. One question arising from this argument relates to the relative roles of visual and phonological coding in reading Chinese.

As Chinese characters directly map onto meaning, it is commonly assumed that the access code during reading is predominantly visual and direct. The results of short-term-memory studies of Chinese characters, however, indicated that phonological coding is needed in processing Chinese characters. In Chu-Chang and Loritz's (1977) study, Chinese high school students were asked to identify previously shown Chinese characters among phonetic distractors, visual distractors, and semantic distractors. It was found that the largest number of errors in recognition was phonetic in nature, next visual, and then semantic. The researchers thus argued that short-term memory representation of written Chinese characters is predominantly phonological. In a study conducted by Yik (1978), Singaporean Chinese performed a short-term memory task of Chinese words in which visual and acoustic similarity of words were manipulated. The results showed a strong acoustic similarity effect, suggesting that acoustic encoding was a basic process in short-term recall of Chinese verbal stimuli. Nevertheless, a significant visual similarity effect was also obtained and the visual effect was particularly pronounced in the absence of acoustic similarity between the characters. In other words, when characters sounded similar, the effect of visual similarity was reduced, but when character sounded dissimilar, the effect of visual similarity was evident.

Tzeng, Hung, and Wang (1977) conducted two experiments to examine whether phonemic similarity affects the visual processing of Chinese characters. In the first experiment, Chinese subjects were visually presented with a list of four character, followed immediately by an oral interference task, and were then asked to recall the previously presented characters in order. In the second experiment, subjects were required to judge whether a single sentence was a normal or an anomalous sentence. The data of both experiments showed that the introduction of phonemic similarity into the test items not only affected the short-term recall of unrelated characters but also affected the reading of meaningful sentences. From the results Tzeng et al. argued for phonetic recoding in reading Chinese materials.

Tzeng and Hung (1980) reported three other experiments related to the issue. In two of the experiments they asked Chinese subjects to make graphemic, phonetic, semantic decision or sentence judgements about strings of characters with or without a concurrent shadowing task. The shadowing task, presumed to disrupt phonetic recoding, required subjects to repeat digits in Chinese delivered through a headphone. The results indicated that only the phonetic decision and the semantic judgement were tremendously affected by the shadowing task, suggesting that phonetic decision requires recoding and that phonetic recoding occurs during sentence processing. The third experiment was a detection task in which Chinese subjects were instructed to read a section of prose and simultaneously circle all characters containing certain grapheme components. It was observed that subjects detected characters most often when the designated grapheme component was embedded as a phonetic in the characters.

Taken altogether, the studies by Tzeng and Hung and their associates investigated the role of phonetic recoding in reading Chinese under a variety of conditions: unrelated character strings, sentences, as well as paragraphs. The results of all the experiments demonstrated that phonetic recoding does play an important role even in reading a logographic orthography. The researchers contended that even if lexical access can occur directly from visual input in reading individual Chinese characters, phonetic recoding is still necessary at the working memory stage of text comprehension.

While not denying phonetic recoding to be a processing strategy of Chinese readers, Treiman, Baron, and Luk (1981) hypothesized that speech recoding would be less used by readers of Chinese. In their study, they compared the performance of Chinese readers and of English readers on two types of false sentences: those contained a homophone word such that the sentence would sound true if read aloud (homophone sentences), and those that did not (control sentences). It was observed that Chinese readers were significantly less impaired by homophone sentences relative to control sentences than were English readers. Treiman et al. thus suggested that speech recoding is less used by readers of Chinese.

Indeed, while most studies demonstrated the occurrence of phonetic recoding in reading Chinese, such evidence does not necessarily preclude the use of visual coding in processing Chinese logographs. As mentioned earlier, Yik (1978), in her study, pointed out that while acoustic encoding is a basic characteristic of short-term recall processes in reading Chinese, visual encoding in short-term memory is also needed as the situation demands. Similar results were obtained in Cheng's (1978) study. Cheng pointed out that, whereas the results of his study indicated the occurrence of speech recoding of Chinese characters in short-term memory, visual coding of the character form is necessary for discriminating homophones.

Summing up of evidence, we can conclude that both visual coding and phonological coding are used in processing reading materials in Chinese. Since Chinese is a morphemical-based orthography, lexical access can occur directly from visual input without phonetic mediation. Phonological coding, however, is usually needed at the working memory stage of text comprehension especially when difficult material is processed. Visual coding, in turn, is necessary for discriminating homophones. As pointed out by Haines and Leong (1983), phonological and visual coding should not be regarded as opposites. Rather, both processing routes are put together to accomplish the reading task. The question that remains is whether and how these processing mechanism distinguish readers of different reading abilities.

Theoretically speaking, the grapheme-sound relationship in Chinese orthography is opaque (Tzeng & Hung, 1984a). Moreover, studies discussed earlier demonstrated empirical evidence for relatively more visual involvement in processing Chinese characters. Hence, there is a higher probability of reading Chinese via a visual route and it is possible that it is the visual coding strategy distinguishing skilled from less skilled Chinese readers. That is to say, the skilled reader of Chinese might be the one who is more often using the visual route to access words, and might be more sensitive to the visual distortions of Chinese characters. A cross-language study by Tzeng and Hung (1984a), however, showed that it is the less skilled reader who is more vulnerable to visual distortion of Chinese words. Tzeng and Hung proposed that less skilled readers, due to the lack of language knowledge and awareness, are deficient in phonological coding which is essential to comprehension. By contrast, skilled readers, with a large knowledge base of orthographic and phonemic structure of the language, are more flexible in adopting either route or both routes in processing texts. While the results of the Tzeng and Hung study are of interest, some methodological weaknesses should be mentioned. The researchers used a measure of oral reading time to differentiate skilled from less skilled readers. The validity of such a crude measure of reading ability is in doubt. Moreover, Tzeng and Hung did not specify which kind of dialect was used in measuring oral reading time. As the subjects were of various dialectical backgrounds, any one of the dialects would favour a certain proportion of the subject group. It was most probably that Mandarin had been used as the medium since all subjects from Taiwan were classified as skilled readers whereas subjects from Hong Kong, Singapore, or Macau were less skilled readers. The authors called attention to the need of specifying the demographic data of the Chinese subjects in future studies. It is argued here that it is more important to select subjects of the same demographic background in order to demonstrate reliable results, especially when oral tasks be involved. Despite the above flaws, the results of the Tzeng and Hung study are in line with most studies in English showing support for the importance of word processing in reading.

Finally, with regard to sentence comprehension processes, Just and Carpenter (1975) used a picture-sentence verification paradigm to investigate sentence processing in Chinese, English, and Norwegian. The results showed considerable universality in the underlying mental operations across these languages. Particularly, they found a remarkable similarity between sentence verification processes in Chinese and English. The researchers therefore contended that, even though Chinese and English writing systems represent their respective spoken language at very different levels, processing rates and modes of processing are similar in these two languages.

2.2.2.4 Summary of empirical issues

A review of the development of psychological research on the Chinese language has revealed certain important changes during the past 60 years of history. Employing research paradigms of experimental psychology, using precise experimental designs, modern instruments and a statistical approach, and a great interest in cognitive psychology with emphasis on information processing, are some characterisitics of today's field of reading psychology in Chinese.

In regard to reading disability research, there have not been many studies on the issue and the findings were controversial. Although precise statements are difficult to make, it appears that the notion that readers of Chinese are immune to reading disability is hardly supported. Further research is needed in order to have more well-founded conclusions.

Within the information processing paradigm, studies of visual lateralization have shown that, beyond the initial perceptual stage, there is similar left hemisphere dominance in processing English as well as Chinese. While relatively more visual involvement has been found in the processing of Chinese characters, speech recoding also occurs in reading Chinese. Furthermore, there is evidence suggesting that there are similar word recognition and sentence comprehension processes in Chinese and English. It seems that in reading Chinese and English, the initial processing may be different, but later processing may converge on similar linguistic analyses. We are thus led to further discussion of the relationship between orthography and reading as proposed by Hung and Tzeng (1981).

2.3 Orthography and Reading: An Overview

In their discussion of cognitive processes in different writing systems, Hung and Tzeng (1981) first identified three distinctive types of orthography: logography, syllabary, and alphabet, on the basis of how written symbols are mapped onto speech. They then attempted to examine the relationship between orthography and reading through an extensive and critical review of a variety of studies.

On analysing the three major writing systems, Hung and Tzeng pointed out that each of the three writing systems assumes a different type of script-speech relation. Logography, such as Chinese characters, represents speech at the morphemic level. Syllabary, such as Japanese kana script, represents speech at the level of the syllable. Finally, an alphabetic system, such as English, represents speech at the morphophonemic level. The various grapheme-meaning relations may imply that there are different cognitive processes entailed in reading different scripts. With such a speculation in mind, the authors began to examine the empirical data revealed in various studies.

Assuming an information processing approach, Hung and Tzeng first looked at studies comparing bottom-up processing in reading different writing systems. They found that different orthographic symbols were processed differently in terms of visual scanning patterns, cerebral lateralization functions, perceptual demands and coding pathways. The writers thus suggested that at the lower levels, human visual information processing is affected by orthographic variation. They then further looked at studies comparing top-down processing in reading different orthographies. From available data Hung and Tzeng found that phonetic recoding occurred in reading different orthographies. They therefore suggested that the requirement of a phonetically based working memory for reading comprehension may be a universal phenomenon independent of orthography. The authors next examined studies of word recognition and found that word recognition processes were very much similar in reading different orthographies. Finally, based on the data of both sentence verification and sentence integration experiments, the authors reported that no processing difference due to orthographic variation was observed in sentence processing.

Taking all the data together, Hung and Tzeng concluded that processing differences for different orthographies seem to occur at the microlevel such as visual scanning and perceptual demands, but not at the macrolevel such as word recognition and sentence comprehension. These findings, according to Hung and Tzeng (1981), suggest that:

> Reading is a universal property, a culture-free cognitive activity, once people in different language systems have acquired the ability to decipher the written symbols (p.406).

It is of interest to note that Hung and Tzeng's observation is in line with the current state of art as described by Gibson and Levin (1975). According to Gibson and Levin (1975), the process of reading may be influence by the nature of different writing systems, but the outcomes are alike. They contend:

> It seems reasonable that different writing systems which relate to language at different levels will involve attention to and abstraction of different aspects of the orthographic system. Readers of a syllabary must search for invariances at one level, readers of an alphabetic system, at another level. But the skilled readers of one system are able to read as efficiently as skilled readers of another (p.165).

Summing up the findings of the studies reviewed in this chapter, it appears that in processing Chinese and English, there may be processing differences in the initial stage, but similar linguistic techniques are implicated in the later stage. It is therefore reasonable to hypothesize that word recognition may bear a similar important relationship to reading comprehension in Chinese as it does to reading comprehension in English. This is the basis upon which the rationale of this study is built.

3. RATIONALE, DEFINITIONS, AND HYPOTHESES

3.1 Rationale

3.1.1 Rationale of the study

It has been shown in Chapter 2 that automatic and rapid word recognition as a determinant of reading comprehension ability is well documented in the reading literature of English. The present study attempts to investigate whether Chinese character recognition also plays a role in distinguishing readers of different abilities similar to that revealed in the English research literature.

Comparing Chinese and English from a theoretical perspective, since the two writing systems relate to language at different levels, they may impose different task demands on their readers. This postulation is supported by the empirical evidence discussed in Chapter 2 that relatively more visual access and visual memory are involved in reading Chinese. Further analysis, nonetheless, reveals the isomorphy of Chinese with English. The invariant graphic-to-morpheme and even graphic-to-sound relationship within each Chinese character resembles the invariant spelling-to-sound relationship embedded in the English orthography. Such an analogy is supported by the visual lateralization experiments at deeper levels of processing and phonetic recoding experiments. Moreover, the comparative study on sentence comprehension by Just and Carpenter (1975) indicated similar fundamental operations implicated in processing Chinese and English. All these points are further substantiated by cross-language experiments reviewed by Hung and Tzeng (1981).

As there are similar processing mechanisms in reading Chinese and English, it seems reasonable to hypothesize that automatic and rapid word recognition is also one determinant of skilled reading in Chinese. It is most probably that the skilled reader of Chinese, just like the skilled reader of English, is the one who identifies words automatically and rapidly whether by visual access or phonological recoding. Such a hypothesis, however, has rarely been tested. The Tzeng and Hung (1984a) study did demonstrate evidence supporting the position. Nevertheless, methodological weaknesses in terms of subject selection and reading ability measurement have reduced the validity of the results of the study. The major purposes of the present study are therefore:

a. To examine whether there are differences in recognition of Chinese characters in skilled and less skilled Chinese readers via a vocalization task and a lexical decision task.

b. To examine the effects of character frequency, character complexity, and character type on Chinese readers' character recognition performance, and the manner in which character frequency, character complexity, and character type interact with levels of reader skill.

3.1.2 Rationale of the experimental tasks

Two experiments are designed in the present study to investigate the performance of character recognition in skilled and less skilled Chinese readers. Experiment 1 employs a vocalization task and Experiment 2 utilizes a lexical decision task. The rationale for employing these two tasks is based on a large body of evidence from reading research in English.

The vocalization task, in which word recognition performance is measured by accuracy and speed of saying a word aloud, has proven to be most useful in laboratory studies of word recognition skill. Studies carried out by Butler and Hains (1979), Curtis (1980), Frederiksen (1978), Haines and Leong (1983), Hammond (1984), Manis (1985), Mason (1978), Perfetti and his associates (e.g. Hogaboam & Perfetti, 1978; Perfetti, Finger, & Hogaboam, 1978; Perfetti & Hogaboam, 1975), and Stanovich (1981) have all pointed to evidence that vocalization accuracy and latency is a measure of word recognition that reveals marked differences between skilled and less skilled readers.

Saying a word aloud, however, is not the only measure of lexical access. Word recognition performance can also be assessed by asking subjects to make a lexical decision on presented items, judging whether they are words or nonwords. It has been pointed out by Haines and Leong (1983) that "(the vocalization task) might bias readers towards phonological coding and that this bias is likely magnified with good readers"(p.79). In this regard, the lexical decision task is of advantage in that in this task lexical access is necessary for making a correct decision but subjects are only required to give a yes/no reponse and therefore might not be biased towards phonological coding. Studies (e.g. Frederiksen, 1978; Haines and Leong, 1983; Perfetti, 1985b, p.95) employing the lexical decision task have also demonstrated word recognition ability differences between skilled and less skilled readers.

On the basis of the research evidence in English reading studies, this study employs a vocalization task and a lexical decision task converging on lexical access of Chinese characters in Chinese readers to examine whether similar results would be obtained.

Additionally, this study also includes a task of matching dot patterns. The purpose of this task is to examine whether there is a performance difference between skilled and less skilled readers in processing non-verbal materials such as dot patterns. Hence, the task serves as a control task to buttress the claim that differences, if any, found in the vocalization task and the lexical decision task are specific to Chinese characters and not to non-verbal visual symbols.

In particular, the rationale for choosing single characters as stimulus units and types of variables included in the experimental tasks is as follows.

3.1.2.1 Stimulus unit

It is acknowledged that modern Chinese words are most often made up of two characters and that single Chinese characters are not strictly equivalent to single English words. However, it is also noted that Chinese characters as the morphemic units in Chinese possess invariant semantic-phonetic properties comparable to the spelling-sound patterns inherent in English words. It is, therefore, argued here that processing single Chinese characters must involve processes (e.g. activiation of the internal lexicon etc.) similar to those in identifying English words.

More important, it has been observed in studies of perception of Chinese characters that Chinese two-character words produce a kind of context effect similar to the word priming effect in English. For example, as discussed earlier, Cheng (1982b) reported that a Chinese character was better perceived when embedded in a word context. Huang (1984) also reported word-context effects in his investigation of perceptual separability of Chinese characters. Since in English studies it is context-free word recognition, not word recognition in context, that best distinguishes skilled from less skilled readers, the present study utilizes single Chinese characters as the stimulus units.

3.1.2.2 Independent variables

It has been shown in studies with English readers that the relationship between word recognition efficiency and reading comprehension ability is not only evident in elementary school children but also holds for adult readers (e.g. Briggs & Underwoods, 1982; Butler and Hains, 1979; Mason, 1978; Hammond, 1984; Stanovich & Bauer, 1978). It is reasonable to propose that character recognition skill as a determinant of reading ability in Chinese will also persist to adulthood with skilled and less skilled college readers. Consequently, Chinese college students are chosen as subjects for investigation in the present study.

In Experiment 1, a vocalization task is used. Whereas the adult reader group is the between-subject independent variable, character frequency and character complexity are chosen as within-subject independent variables for investigation. As noted before, English skilled readers are often more accurate and faster at identifying printed words than are less skilled readers. Moreover, the magnitude of the difference between skilled and less skilled readers in word decoding depends on word frequency and word length. The differences between ability groups are greater for low frequency words and for longer words (Haines & Leong, 1983; Hogaboam & Perfetti, 1978; Marr & Kamil, 1981; Perfetti & Hogaboam, 1975). In Chinese studies, although frequency has been observed to be one of the most potent variables affecting character or word recognition, only a few studies have investigated the effect of word frequency on word recognition and reading ability. For example, Tzeng and Hung (1984a) observed a word frequency effect in a lexical decision task with skilled and less skilled Chinese readers. The results were in line with those English studies suggesting that less skilled readers are much more sensitive to the frequency effect.

With regard to word length, since all Chinese characters are in squared shape, there is no variation among characters in terms of length. Nevertheless, character complexity in terms of number of strokes is comparable to word length in English. To this writer's knowledge, no systematic study has directly investigated the effect of character complexity on character recognition and its relationship to reading ability. Some studies (e.g. Yeh & Liu, 1972; Cheng, 1982b) did report a relationship between character complexity and recognition threshold and recognition accuracy. Still other researchers (e.g. Leong, 1972; Taylor & Taylor, 1983) argued for the importance of the analysis of character constituents rather than the number of strokes in learning and identifying Chinese characters. In view of the scarcity of information concerning the effects of character frequency and complexity on character recognition and reading ability, it is of interest to examine how these two variables influence character recognition and the manner in which they interact with reading ability.

In Experiment 2, a lexical decision task is employed. While character complexity is retained as one within-subject independent variable for investigation, character frequency is replaced by character type with real and pseudo-characters as its levels. The reason is that pseudo-characters cannot be classified according to frequency usage but still can be classified as simple and complex in terms of number of strokes. Results of English studies (e.g. Briggs & Underwoods, 1982; De Soto & De Soto, 1983; Haines & Leong, 1983; Hogaboam & Perfetti, 1978; Mason, 1978) have indicated marked difference between skilled and less skilled readers in naming pseudowords and in making a lexical decision about pseudowords. Since Chinese pseudo-characters are not decodable, its effect on performance of skilled and less skilled readers cannot be investigated via a vocalization task. It is, however, still possible for Chinese readers to make lexical decision about real and pseudo-characters. As a result, in the lexical decision task character type and character complexity are chosen as independent variables for investigation.

3.1.2.3 Dependent variables

In the two experiments as well as in the control task, two separate dependent variables are accuracy rate and reaction time.

As reviewed in Chapter 2, both accuracy and reaction time are important measures of word recognition. Accuracy rate is one of the most often used measures of word recognition skill and has been found to be highly correlated with reading ability. Reaction time has been implicated as an indicator of speed of word recognition and reader ability differences within this context have also been observed. While both accuracy and reaction time are strong predictors of reading ability of English readers, a slightly different pattern of results has been reported (see Perfetti, 1985b). Skilled readers are faster in decoding speed in all cases and their superiority increases for low frequency words and pseudowords, whereas their advantage in accuracy is evident for low frequency words and pseudowords but not for high frequency words. Moreover, recent studies (e.g. Leong et al., 1985) have indicated that accuracy and reaction time do not necessarily measure the same perceptual processes. Therefore, the present study employs both measures to allow for separate analyses and comparisons of the analyses on the performance of skilled and less skilled readers.

3.2 Definitions

For the purpose of this study, the major terms are defined as follows:

3.2.1 Character recognition

The term character recognition refers to the process of extracting information from printed characters, activating a location in the mental lexicon, and resulting in semantic information available to consciousness (adapted from Stanovich, 1982a, p.486). The term in this study is used interchangeably with character decoding referring to processes essential to lexical access and does not indicate whether the lexicon is accessed via a visual or a phonological path. Operationally, character recognition in this study is defined as: 1/ the accuracy and speed of naming a printed character, and b/ the accuracy and speed of making a lexical decision on a printed character.

3.2.2 Reading ability

The term refers to reading comprehension ability as measured by a comprehension test adapted from past HKCEE (Hong Kong Certificate of Education Examination) Chinese Reading Comprehension papers.

3.2.3 Skilled readers

The term refers a group of Chinese readers who scored at the top range (above 84%) of the comprehension test.

3.2.4 Less skilled readers

This term refers to a group of Chinese readers who scored at the bottom range (below 64%) of the comprehension test.

3.3 Hypotheses

On the basis of the previous discussion, the following hypotheses are formulated:

3.3.1 Control task: Matching dot patterns

Hypothesis 1

It is hypothesized that there will be no significant accuracy rate difference between skilled and less skilled readers in matching dot patterns.

Hypothesis 2

It is hypothesized that there will be no significant latency difference between skilled and less skilled readers in matching dot patterns.

3.3.2 Experiment 1: Vocalization Task

Hypothesis 3

It is hypothesized that skilled readers will display a significantly higher vocalization accuracy rate than less skilled readers in naming Chinese characters.

Hypothesis 3 can be broken into:

3.1 The vocalization accuracy difference between skilled and less skilled readers will be greater for low frequency characters than for high frequency characters.

3.2 The vocalization accuracy difference between skilled and less skilled readers will be greater for complex characters than for simple characters.

Hypothesis 4

It is hypothesized that skilled readers will show significantly shorter vocalization latencies than less skilled readers.

Hypothesis 4 can be broken into:

4.1 The vocalization latency difference between skilled and less skilled readers will be greater for low frequency characters than for high frequency characters.

4.2 The vocalization latency difference between skilled and less skilled readers will be greater for complex characters than for simple characters.

3.3.3 Experiment 2: Lexical Decision Task

Hypothesis 5

It is hypothesized that skilled readers will display a significantly higher lexical decision accuracy rate than less skilled readers.

Hypothesis 5 can be broken into:

5.1 The lexical decision accuracy difference between skilled readers and less skilled readers will be greater for pseudo-characters than for real characters

5.2 The lexical decision accuracy difference between skilled and and less skilled readers will be greater for complex than for simple characters.

Hypothesis 6

It is hypothesized that skilled readers will display a significantly shorter lexical decision latencies than less skilled readers.

Hypothesis 6 can be broken into:

6.1 The lexical decision latency difference between skilled readers and less skilled readers will be greater for pseudo-characters than for real characters

6.2 The lexical decision latency difference between skilled and less skilled readers will be greater for complex than for simple characters.

4. METHOD

A comprehension test, a control task and two experiments were included in this study. The method in general for the study will first be presented. Experimental design and procedure specific to each experiment will then be described.

4.1 General Method

4.1.1 Subjects

A pool of potential subjects was developed by administering a Chinese reading comprehension test to 166 Chinese students who were either studying at the University of Alberta or at Alberta College. All potential subjects participated on a volunteer basis. The mean of the comprehension test for the potential subject pool was 73 (full scale range of 100) with a standard deviation of 10.25. Based on the comprehension result, those who scored at the top range or at the bottom range were then invited to participate in the experimental session of the study. Some students were dropped from the sample because of time conflict or because of unwillingness to continue. Finally, 23 skilled readers from the top range (84-92) and 23 less skilled readers from the bottom range (48-64) were retained and completed the experiments. Both the skilled and less skilled reader groups contained 11 males and 12 females. The mean reading comprehension scores were 86.78 (S.D.=2.15) for skilled readers and 57.30 (S.D.=4.77) for less skilled readers. Therefore, subjects of this study were not selected from extreme groups of the normal distribution of reading ability. Rather, the less skilled readers of this study were of average reading comprehension skills. They were classified as less skilled readers as comparing to the superior comprehension performance of the skilled readers. All subjects were native speakers of Chinese with Cantonese as their most fluent dialect. They grew up and were educated through high school in Hong Kong. All but two of the subjects passed (grade E or above) the Chinese Language subject in the Hong Kong Certificate of Education Examination (a public graduation examination for high school students). The average grade was C for the skilled reader group and it was between D and E for the less skilled reader group.

4.1.2 Comprehension Materials

Comprehension ability was assessed with a comprehension test adapted from past HKCEE (Hong Kong Certificate of Education Examination) Chinese Reading Comprehension papers (1975 - 1979) which were orignially designed to test the reading proficiency of Hong Kong high school graduates. Of the 12 selected reading paragraphs, 5 were written in modern Chinese and 7 in classical Chinese (see Appendix A for sample paragraphs and Appendix B for English versions of the samples). The selected paragraphs were of various styles (narrative descriptive, or analytic) that each consisted of a set of 4 to 5 multiple-choice-type questions requiring recall of passage main ideas, details, or inferential analysis. There were 50 questions in total. All questions were selected with a relative point-biserial correlation coefficient above 0.3, which indicated that these items had a moderate correlation with the comprehension scores of the examinees who participated in the past examinations. With 2 marks for each question, the full scale range of the comprehension test was 100.

4.1.3 Apparatus

The apparatus described below was used for the two experiments as well as for the control task.

A sony microphone and a Lafayette voice-operated relay indicator (model 6602A), with sensitivity set at the maximum possible, were used in conjunction with Kodak Carousel slide projector (model AF-2) equipped with a tachistoscopic shutter, a projection screen, and a Lafayette program timer (model 52020) connected with a Lafayette digital clock counter (model 54417-A). The program timer started when the project's shutter opened to display a slide and stopped at the subject's inital vocal response via the voice-operated relay. The apparatus thus allowed the measurement of the response latencies of matching dot patterns, vocalization, or lexical decision, defined as the elapsed time from the onset of the visual stimulus to the onset of the subject's vocal response.

4.1.4 General Procedure

Subjects were tested in two sessions. The first session consisted of collecting reading comprehension scores for all potential subjects. In the second section, two experiments and a control task were conducted with the selected subjects.

First, the Chinese reading comprehension test was administered to 166 Chinese students as described before, 6 to 8 persons at a time, from February to March, 1985. The subjects were instructed to read the passages carefully and choose the best answer for each question following the passages. They were also told to finish the test within 1 hour and 15 minutes. Based on the comprehension scores, 23 skilled and 23 less skilled readers were selected to participate in the experimental session of the study.

About a month after the Chinese reading comprehension test was administered, the selected subjects were asked to participate in the experimental session including two experiments and a control task. For all experiments, the selected subjects were tested individually in a quiet room. Each subject sat at a table approximately 1.2 m. for the viewing screen, in a position that was comfortable for him/her to clearly view the stimuli and respond. The projected stimulus was of 30 cm. square on the screen. Experimental stimuli were always preceded by several practice items. Subjects were instructed to respond to presented stimuli as quickly and as accurately as possible. The whole experimental session required about 40 minutes for each subject.

4.2 Control Task: Matching Dot Patterns

4.2.1 Design

The task of matching dot patterns served as a control task in this study. Reader group was the independent variable with skilled readers and less skilled readers as its levels. Two separate dependent variables were accuracy and reaction time of matching dot patterns. This task allowed two separate t-tests, one for the mean reaction difference and one for the mean accuracy rate difference between skilled and less skilled readers.

4.2.2 Stimuli

The stimuli in the task of matching dot patterns were taken from Curtis (1980). They were pairs of dot patterns generated by randomly filling in five dots in a 3 x 3 matrix (see Appendix C). There were 20 test items along with 5 practise items. The different pairs were formed by moving one dot in a given row one column over relative to the original pattern. The stimuli were photographed for slides.

4.2.3 Procedure

For the control task, the subjects were told that pairs of dot patterns would be presented one pair at a time on the screen and that their task was to say "yes" if both items in the pair were the same and to say "no" if they were different. They were also instructed to repond as quickly and as accurately as possible. Each subject was familiarizied with the microphone and given 5 items for practice. If the subjects did not respond appropriately during the warn-up slides, the instructions were repeated. Following the practice trials, the 20 test slides, arranged in a random order, were presented. Response latencies and accuracy were recorded after each trial. If no response occurred after 5 seconds had elapsed, the shutter were closed, the absence of response was recorded and scored as an error, and the projector advanced to the next slide. It took about 7 minutes for each subject to finish the control task.

4.3 Experiment 1: Vocalization Task

4.3.1 Design

In experiment 1, a vocalization task was used to investigate the performance of character recognition of Chinese readers. The vocalization task employed a 2x2x2 factorial design. Reader group was the first factor, consisting of skilled readers and less skilled readers as its levels. Character complexity was the second factor, with simple characters and complex characters as its levels. Character frequency was the third factor, with high frequency characters and low frequency characters as its levels. Hence, the independent variables of the vocalization task were reader group, character complexity, and character frequency. The two separate dependent variables were accuracy and latency of vocalization. The vocalization task was designed to permit two separate 2(reader group) x 2(character complexity) x 2(character frequency) analyses of variance with repeated measures on the last two factors.

4.3.2 Stimuli

The stimuli in Experiment 1 for the vocalization task were 80 experimental characters along with 8 practice items (see Appendix D). All characters were formed by two or more constituents and taken from *Current Vocabulary Used in Primary School* developed by Curriculum Development Section, Hong Kong Education Department (1975). Hence, all characters were of grade 6 or of lower grade levels and should be known by all subjects in the study. Moreover, all characters were selected in terms of frequency (high, low) and complexity (simple, complex). Character frequency counts were based on a frequency analysis of a corpus of 1,177,984 occurrences of 4,583 Chinese characters developed by Cheng (1982a). High frequency characters had greater than 900 occurrence counts per million with a mean frequency of 2169, whereas low frequency characters had less than 30 occurrence counts with a mean frequency of 16. Character complexity was measured in terms of the number of strokes in each character. Simple characters had 5 to 9 strokes with an average of 7.4 strokes, whereas complex character had 12 to 16 strokes with an average of 13.7 strokes. Accordingly, all characters used in the vocalization task were classified into 4 classes.

Class 1 consisted of 20 high frequency, simple characters. Character frequency ranged from 925 to 5548 with a mean frequency of 2070. Number of strokes in each character ranged from 5 to 9 and the average number of strokes was 7.40.

Class 2 contained 20 low frequency, simple characters. Character frequency ranged from 4 to 30 with a mean frequency of 16. Number of strokes in each character ranged from 5 to 9 and the average number of strokes was 7.35.

Class 3 included 20 high frequency, complex characters. Character frequency ranged from 903 to 5640 with a mean frequency of 2268. Number of strokes in each character ranged from 12 to 16 and the average number of strokes was 13.65.

Class 4 comprised of 20 low frequency, complex characters. Character frequency ranged from 3 to 30 with a mean frequency of 15. Number of strokes in each character ranged from 12 to 16 and the average number of strokes was 13.75.

All characters were written in regular style (楷書) of 1.5 cm. square on white cards and photographed for slides.

4.3.3 Procedure

For each subject, immediately after the administration of the control task, Experiment 1 was conducted. Each subject was told that Chinese characters would be presented one at a time on the screen and that their task was to name each character as fast and as accurately as possible. Following 8 practice trials, the 80 test trials aranged in a random order were presented. Presentation procedure was just the same as that in the control task. It took about 15 minutes for each subject to finish Experiment 1.

4.4 Experiment 2: Lexical Decision Task

4.4.1 Design

In Experiment 2, the character recognition performance of Chinese readers was investigated by using a lexical decision task. The design of the lexical decision task was similar to that of the vocalization task, exeept that the third factor was replaced by character type with real and pseudo-characters as its levels. Accuracy and latency were again the two separate dependent variables used in this experiment. As a result, the lexical decision task allowed two separate 2(reader group) x 2(character complexity) x 2(character type) analyses of variance with the last two measures repeated.

4.4.2 Stimuli

The stimuli in the lexical decision task were also 80 experimental characters along with 8 practice items (see Appendix E). All characters were classified in terms of character type (real, pseudo) and character complexity (simple, complex). Real characters were selected from the same source as described for the vocalization task, with a mean frequency per million of 1197. Pseudo-characters were those acceptable orthographic patterns derived from the experimental characters. The rule for constructing pseudo-characters was either replacing one similar constituent in the original character or transposing the constituents of the original character without violating the usual orthographic patterns in Chinese characters (Cheng, 1982b). The rule for classifying characters into simple and complex was just the same as described for the vocalization task. Consequently, there were 4 classes of characters used in the lexical decision task.

Class 1 consisted of 20 simple real characters. Character frequency ranged from 2 to 5272 with a mean frequency of 1378. Number of strokes in each character ranged from 5 to 9 and the average number of strokes was 7.25.

Class 2 contained 20 simple pseudo-characters derived from Class 1. Number of strokes in each character was the same as in class 1 characters.

Class 3 included 20 complex real characters. Character frequency ranged from 3 to 3380 with a mean frequency of 1016. Number of strokes in each character ranged from 12 to 16 and the average number of strokes was 13.55.

Class 4 were 20 complex pseudo-characters derived from class 3. Number of strokes in each pseudo-character was the same as in class 3 characters.

The stimuli were prepared in the same manner as described for the vocalization task.

4.4.3 Procedure

For each subject, Experiment 2 was carried out immediately after Experiment 1. The experimental procedure for Experiment 2 was similar to that of experiment 1 but the subjects were told that they were going to see Chinese characters or pseudo characters one at a time on the screen and that their task was to say "yes" to a character and "no" to a pseudo character as quickly and accurately as possible. Following 8 practice trials with characters and pseudo characters, 80 text items arranged in a random order were presented. It took about 15 minutes for each subject to finish Experiment 2.

5. RESULTS AND DISCUSSION

The results and discussion of the present study will be presented in four sections. First, the results of the control task will be summarized and discussed. The second section will deal with the results and discussion of Experiment 1. The results and discussion of Experiment 2 will be given in the third section. Finally, a general discussion integrating the results of the overall study will be presented.

5.1 Control Task: Matching Dot Patterns

The task of matching dot patterns served as a control task in this study to examine the possibility that general processing speed of performance might differentiate skilled and skilled readers. Two separate t-tests, one for the accuracy data and one for the response latency data, comprised the main results of the control task.

5.1.1 Matching dot pattern accuracy

The accuracy rate of matching dot patterns was caculated for each subject. The means and standard deviations of the accuracy rate values for the subjects by reading ability are given in Table 1. A t-test was performed to provide direct comparision of the two reader groups on accuracy of matching dot patterns. The result showed that there was no significant difference between the two reader groups in how accurately they matched dot patterns [$t(44) = .78$, $p > .05$]. This finding therefore supported Hypothesis 1 which predicted that there would be no significant difference of accuracy rate between skilled and less skilled readers in matching dot patterns. Indeed, as shown in Table 1, skilled readers (Mean=96.30%) and less skilled readers (Mean=95.22%) were both highly accurate in matching dot patterns. The difference between the two groups was only 1.08%.

Table 1

Means and Standard Deviations for Accuracy Rates of Matching Dot Patterns

Reader ability	Mean	S.D.
Skilled	96.30 %	5.9 %
Less Skilled	95.22 %	3.1 %

5.1.2 Matching dot pattern latency

For the latency data of matching dot patterns, latencies for which the response was incorrect were not included. Trials on which the subject did not respond were scored as errors and dropped from the analysis. Also, trials on which the response was correct but did not stop the timer were also eliminated. Across all subjects, the total number of correct responses that did not stop the timer was 7 out of a total of 920 response (0.76%). In other words, such cases were rare and would not constitute a problem affecting the results of analysis.

The mean response latency of matching dot patterns was computed for each subject. Table 2 shows the means and standard deviations of response latencies for the two comprehension groups. As with the accuracy data, a t-test was carried out to compare the response latencies of the two groups. Again, the result showed that there was no significant difference between the two comprehension groups [$t(44)=1.40$, $p>.05$]. This finding thus gave support to Hypothesis 2 which stated that there would be no significant response latency difference between skilled and less skilled readers in matching dot patterns. As shown in Table 2, skilled readers were a bit faster (66 msec) than less skilled readers in matching dot patterns, but this difference was not significant.

In short, both the results of accuracy and latency of matching dot patterns showed that skilled and less skilled readers were not different in accuracy and speed of processing non-verbal materials such as matching dot patterns. Therefore, it is argued that differences, if any, found in Experiment 1 and Experiment 2 between skilled and less skilled readers are specific to verbal symbols and not to non-verbal visual symbols.

Table 2

Means and Standard Deviations for Response Latencies of Matching Dot Patterns (Msec)

Reader ability	Mean	S.D.
Skilled	995	169
Less Skilled	1061	152

* Latency values are rounded to the nearest millisecond.

5.2 Experiment 1: Vocalization Task

The results of Experiment 1 were first analysed with two separate repeated measured ANOVA'S, one for the vocalization accuracy data and one for the vocalization latency data. In later analyses, correlational and multiple regression analyses were performed based on the vocalization latency data.

5.2.1 Vocalization accuracy

The accuracy rate data of vocalization performance were subjected to a 2 (reader ability) x 2 (character frequency) x 2 (character complexity) analysis of variance with the last two factors repeated. For each subject, accuracy rate was calculated for each of the four conditions -- high frequency simple characters, high frequency complex characters, low frequency simple characters, and low frequency complex characters. Table 3 shows the means and standard deviations of the accuracy rate values for the subjects by reader ability, character frequency, and character complexity. The means of accuracy rate for the two groups are illustrated graphically in Figure 1. Table 4 presents the results of the ANOVA.

A highly significant main effect for reader ability was observed [F(1,44)=35.16, p<.0001]. The main effect for reader ability indicated that skilled readers were significantly more accurate than less skilled readers in naming Chinese characters. The mean accuracy rates for skilled and less skilled readers were 94.13% and 87.88% respectively. In other words, overall skilled readers were 6.25% more accurate than less skilled readers in naming Chinese characters. Whereas a nonsignificant main effect was obtained for character complexity [F(1,44)=0.57, p>.05], the main effect for character frequency was significant [F(1,44)=263.57, p<.0001]. The main effect for character frequency showed that high frequency characters had a greater vocalization accuracy rate than low frequency characters. The mean accuracy rate was 99.67% for high frequency characters and 82.33% for low frequency characters.

Table 3

Means and Standard Deviations[a]
for Vocalization Accuracy Rates

Reader ability	character frequency	high		low	
	character complexity	simple	complex	simple	complex
Skilled		99.34% (1.73%)	100.00% (0%)	89.34% (6.27%)	87.83% (7.35%)
Less Skilled		99.57% (1.44%)	99.78% (1.04%)	74.78% (7.90%)	77.39% (10.96%)

[a] Standard Deviations are presented in parentheses.

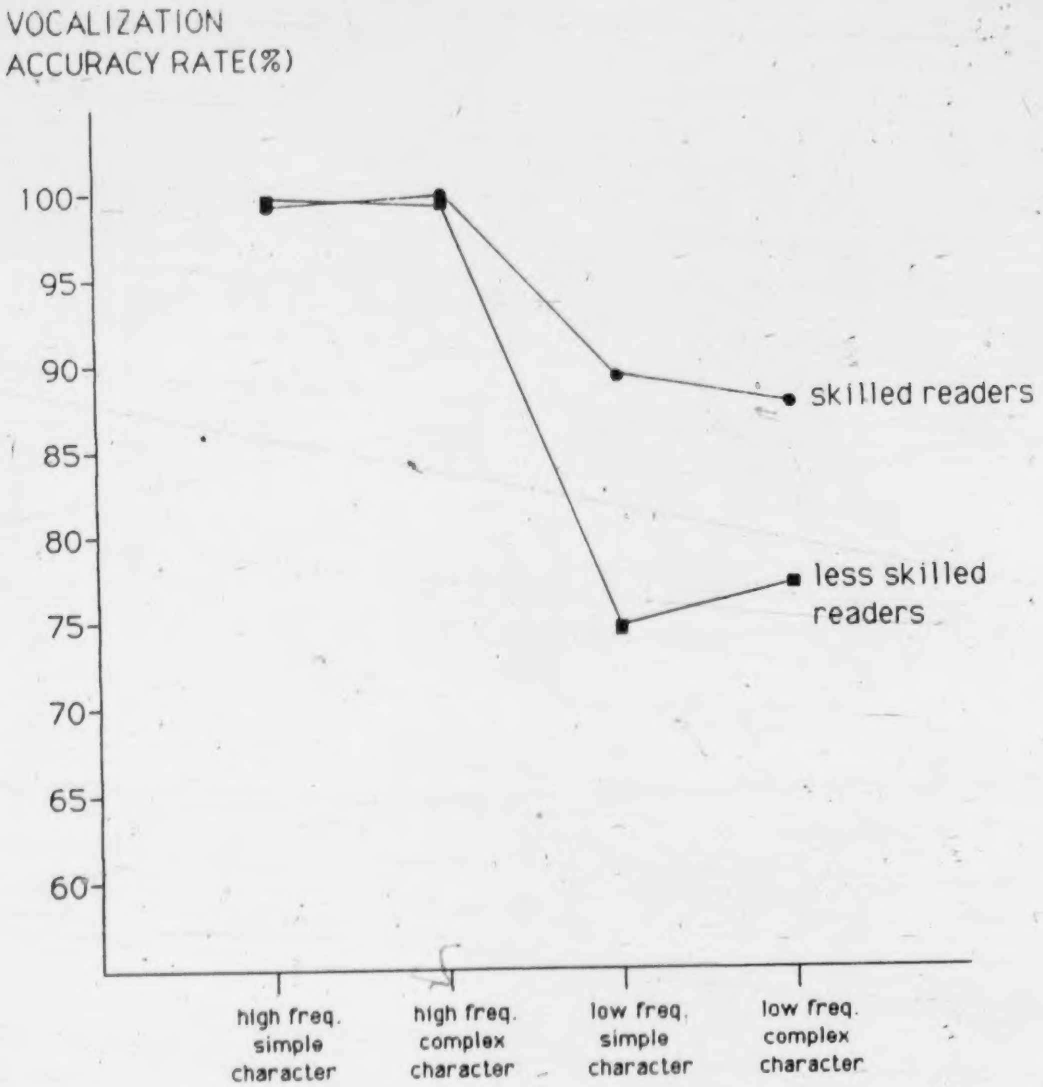

Figure 1. Means of Vocalization accuracy rate for skilled and less skilled readers as a function of character frequency and character complexity, collapsed over levels.

Table 4

ANOVA for Vocalization Accuracy Data
Involving 2 (Reader ability) x 2 (Character frequency)
x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	1796.88	35.16****
Error	44	51.10	
Within			
W1 (Character frequency)	1	13826.22	263.57****
W1 x B1	1	1796.88	34.25****
Error	44	52.46	
W1 (Character complexity)	1	11.01	0.57
W2 x B1	1	39.27	2.02
Error	44	19.45	
W1 x W2	1	0.14	0.01
W1 x W2 x B1	1	59.92	3.31
Error	44	18.10	

**** $p < .0001$

Of the interaction effects, only the reader ability by character frequency interaction was significant [F(1,44)=34.25, p<.0001], and is illustrated graphically in Figure 2. Multiple comparisons using the Tukey (a) method (Winer, 1971) were utilized to determine specific differences between the two reader groups. Results indicated that the difference between the two groups was significant (p<.05) for low frequency characters but not for high frequency characters. It appeared that both groups had experienced a ceiling effect for high frequency characters as they both scored at 99.67% correct for high frequency characters. In contrast, skilled readers were 12.5% more accurate than less skilled readers in naming low frequency characters. All other interactions, reader ability by character complexity, character frequency by character complexity, and reader ability by character frequency by character complexity, were not significant.

Integrating the results, the main effect for reader ability of the above analysis gave some support to Hypothesis 3 which predicted that skilled readers would show a significantly higher vocalization accuracy rate than less skilled readers. Nevertheless, this main effect must be qualified somewhat with reference to the significant interaction between reader ability and character frequency. As revealed in multiple comparisons of the means involved in this interaction, the advantage of skilled reders in vocalization accuracy was restricted to low frequency characters. Hypothesis 3 therefore received partial support.

Hypothesis 3.1, which stated that the vocalization accuracy difference between skilled and less skilled readers would be greater for low frequency characters than for high frequency characters, was supported. Skilled readers and less skilled readers showed great difference in vocalization accuracy for low frequency characters but no difference for high frequency characters.

Since there was no significant interaction between reader skill and character complexity, Hypothesis 3.2 was not supported. Similar accuracy differences between

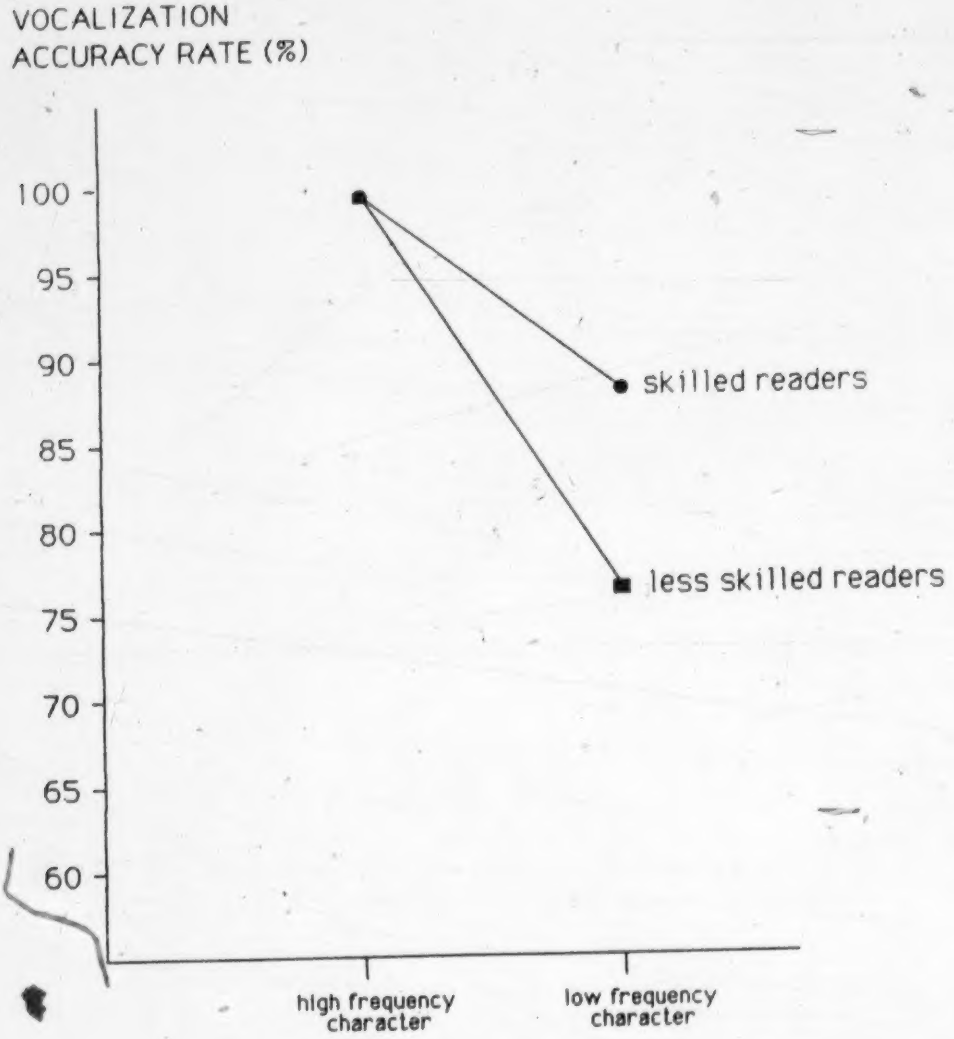

Figure 2. Means of Vocalization accuracy rate as a function of character frequency and reader ability.

skilled and less skilled readers were observed for simple characters (7.18%) and for complex characters (5.32%).

In sum, the results of vocalization accuracy revealed that skilled readers were more accurate than less skilled readers in naming Chinese characters. The superority of skilled readers, however, was restricted to low frequency characters. Character complexity as defined in this study appeared not to an important factor affecting the vocalization accuracy performance of both skilled and less skilled leaders.

5.2.2 Vocalization latency

As in the dot matching latency analysis, only the latencies of correct responses were included in the vocalization latency analyses. Correct responses which did not stop the timer were also eliminated. Across all subjects, the total number of correct response which did not stop the timer was 12 out of a total of 3680 responses (0.33%). The incidence was low and therefore would not constitute a problem affecting the results of the anaysis.

For each subject, mean vocalization latencies were calculated for the four classes of characters. Analyses were performed on subject means. In order to provide more stringent results, parallel analyses were also carried out on log-transformed data of these means. Since the analyses for both mean scores and log-transformed scores provided essentially identical patterns of results, the mean score analyses are the basic data reported for ease of interpretation. For the ANOVA results of the log-transformed data of vocalization latency means, see Appendix F.

A 2 (reading ability) x 2 (character frequency) x 2 (character complexity) analysis of variance with the last two factors repeated was performed on the mean vocalization latency data. Table 5 presents the means and standard deviations of the vocalization latency values for the subjects by reader ability, character frequency, and character complexity. The means are graphically illustrated in Figure 3. Table 6 shows

8

Table 5

Means and Standard Deviations[a] for Vocalization Latencies[b] (Msec)

Reader ability	Character frequency	high		low	
	character complexity	simple	complex	simple	complex
Skilled		684 (99)	690 (113)	981 (172)	1011 (176)
Less Skilled		785 (138)	786 (128)	1236 (278)	1337 (257)

[a] Standard Deviations are presented in parentheses.

[b] Latency values are rounded to the nearest millisecond.

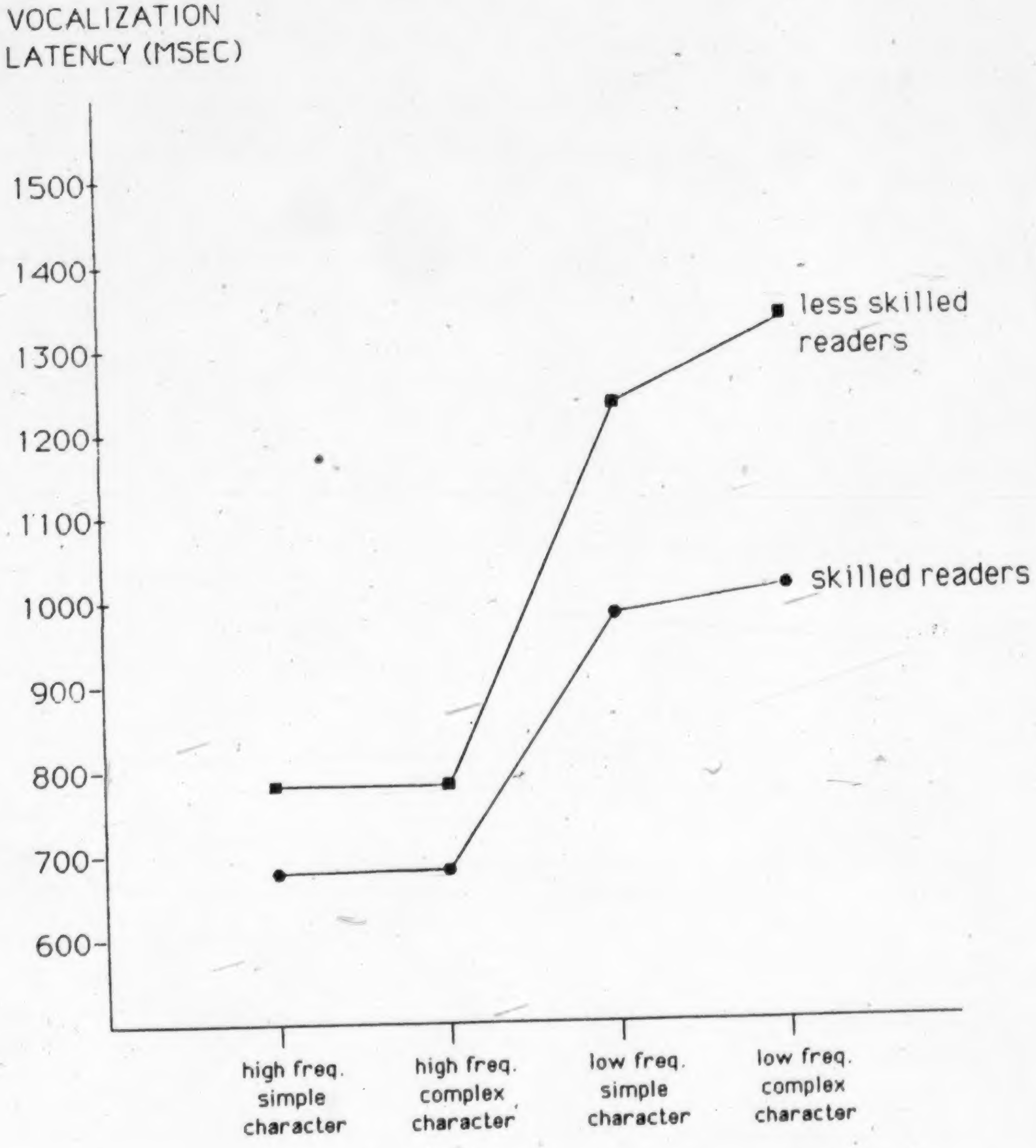

Figure 3. Means of Vocalization latency for skilled and less skilled readers as a function of character frequency and character complexity, collapsed over levels.

the results of the ANOVA for the data.

There was a highly significant main effect for reader ability [F(1,44)=17.79, p<.0001]. The main effect for reader ability revealed that skilled readers were significantly faster than less skilled readers in pronouncing Chinese characters. The mean vocalization latency was 841 msec for skilled readers, and 1036 msec for less skilled readers. Overall, skilled readers were 195 msec faster than less readers in naming Chinese characters. The main effect for character frequency was also significant [F(1,44)=308.20, p<.0001], showing that vocalization latencies decreased with increasing character frequency for both comprehension groups. The mean vocalization latencies for high frequency characters and for low frequency characters were 736 msec and 1141 msec respectively. A significant main effect for character complexity was also obtained [F(1,44)=13.23, p<.001]. The main effect for character complexity indicated that vocalization latencies increased with increasing character complexity. The mean vocalization latency for simple characters was 922 msec and it was 955 msec for complex characters.

While all the main effects were highly significant, these results should be interpreted in view of the two significant interactions between the variables. Whereas the interaction between reader skill and character complexity was not significant [F(1,44)=3.01, p>.05], a significant reader skill by character frequency interaction was observed [F(1,44)=17.24, p<.001] and is depicted graphically in Figure 4. The significant interaction between reader ability and character frequency appeared to be due to the greater increase in vocalization latency on low frequency characters for less skilled readers relative to skilled readers. To further determine specific differences, multiple comparisons using the Tukey (a) procedure were made between the vocalization latency means of the two reader groups. Results showed that the vocalization latency differences between the two groups were significant (p<.05) for both high frequency and low frequency characters. Whereas skilled and less skilled readers showed smaller

Table 6
ANOVA for Vocalization Latency Data (Mean Scores)
Involving 2 (Reader ability) x 2 (Character frequency)
x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	1739413.59	17.79***
Error	44	97748.68	
Within			
W1 (Character frequency)	1	7542720.20	308.20****
W1 x B1	1	421836.63	17.24***
Error	44	24473.19	
W2 (Character complexity)	1	54269.57	13.23***
W2 x B1	1	12359.04	3.01
Error	44	4102.65	
W1 x W2	1	43958.35	9.71**
W1 x W2 x B1	1	17452.52	3.85
Error	44	4527.93	

**** P < .0001
*** P < .001
** P < .01

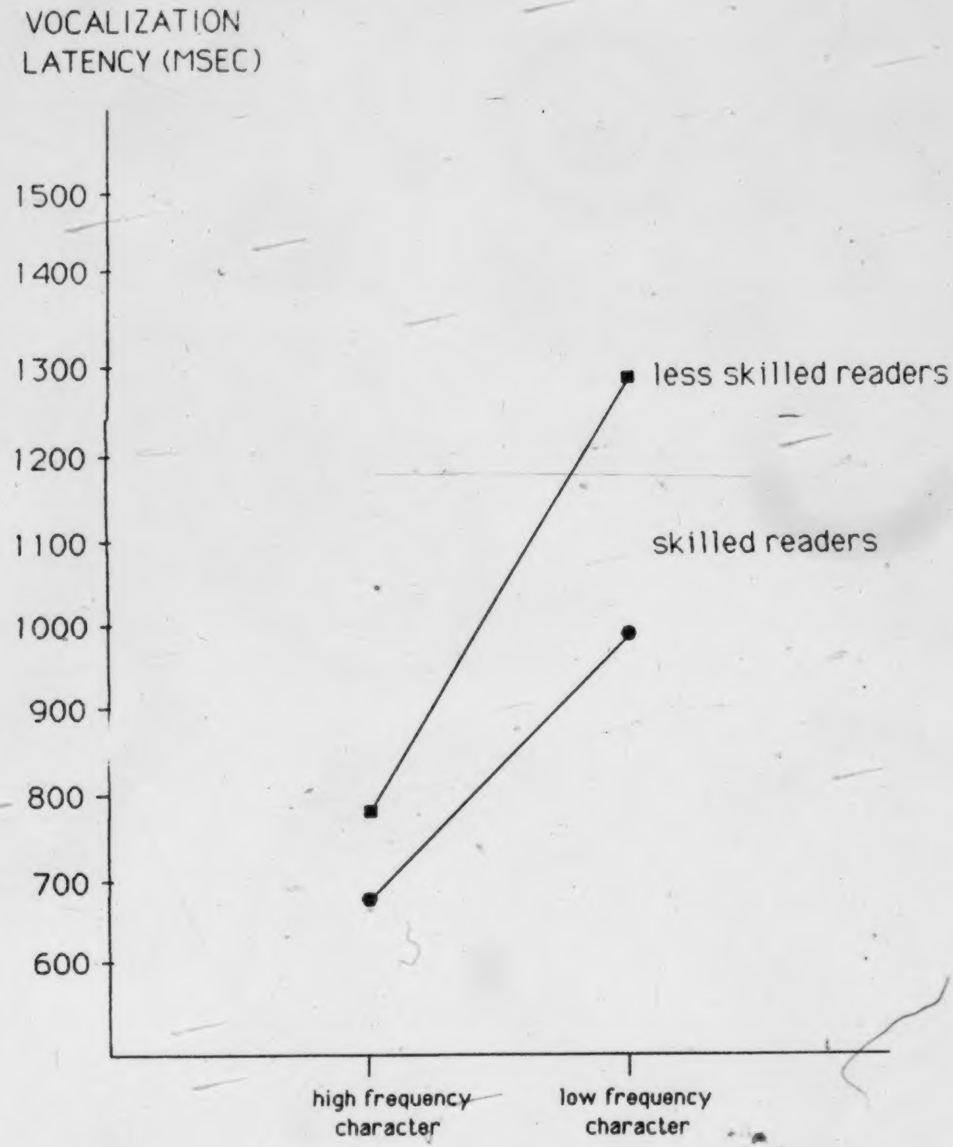

Figure 4. Means of Vocalization latency as a function of character frequency and reader ability.

difference (99 msec) on mean vocalization latency for high frequency characters, a marked difference (290 msec) was found between the two groups for low frequency characters.

The character frequency by character complexity interaction was also significant [F(1,44)=9.71, p<.01]. Multiple comparisons of the means involved in this interaction showed that, except for the means between high frequency simple and high frequency complex characters, all comparisions were significant (p<.05).

The three-way interaction -- reader skill by character frequency by character complexity -- was of marginal significance [F(1,44)=3.85, p=0.56] and is illustrated graphically in Figure 5. Since a trend was still evident, multiple comparisons using the Tukey (a) method were carried out. Significant differences (p<.05) were found over all comparisons between skilled and less skilled readers showing that skilled readers responded more rapidly than less skilled readers in all conditions. Within the skilled reader group, response latencies did not differentiate the two levels of complexity for both high and low frequency characters, whereas for less skilled readers, response latencies did not differentiate the two levels of complexity for only high frequency characters.

When log-transformed subject means were used, except for the last mentioned marginally significant three-way interaction which became nonsignificant (p=.079), the pattern of signicance of the ANOVA with mean scores, however, was replicated.

The above vocalization latency analysis supported Hypothesis 4 which predicted that skilled readers would display overall shorter latencies than less skilled readers in naming Chinese characters. The main effect for reader ability provided evidence that skilled readers were faster in naming Chinese characters as compared to less skilled readers. Hypothesis 4 was supported even in the presence of the interaction effects. As multiple comparisons of the means involved in these interactions revealed that skilled readers in all cases were significantly more rapid at pronouncing Chinese

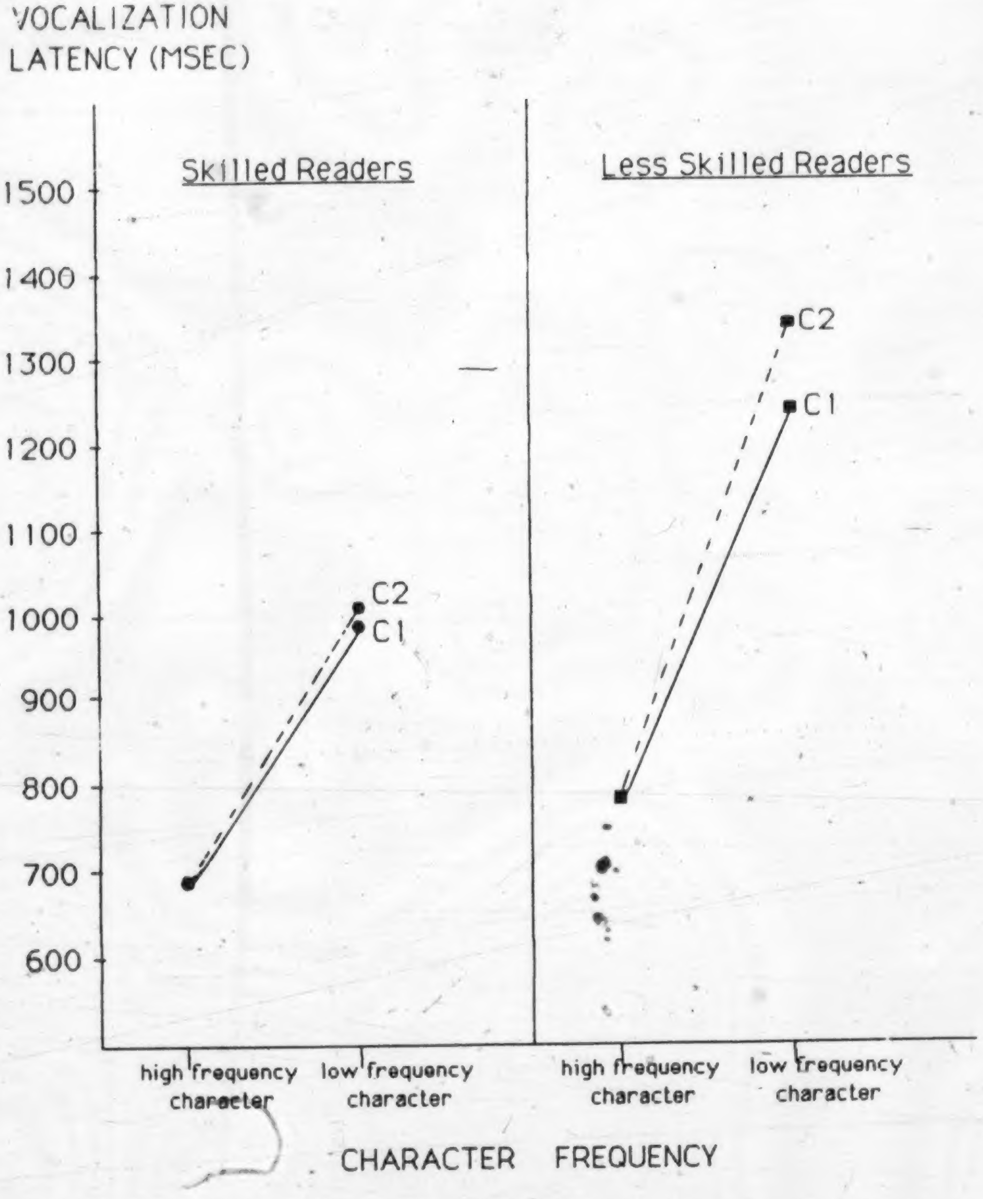

Figure 5. Vocalization latency means as a function of character frequency and character complexity for skilled and less skilled readers. (C1= simple characters, C2= complex characters)

characters than less skilled readers, Hypothesis 4 was clearly supported.

As predicted in Hypothesis 4.1, the two comprehension groups displayed greater vocalization latency difference for low frequency characters than for high frequency characters. The differences between the two groups were significant for both two character frequency levels. The magnitude of difference for low frequency characters, however, was almost three times the difference for high frequency characters.

As in the vocalization accuracy analysis, no significant interaction between reader skill and character complexity was obtained. There was thus no support for Hypothesis 4.2. The two reader groups demonstrated large differences for both simple (179 msec) and for complex (211 msec) characters.

Comparing the results of vocalization accuracy and those of vocalization latency, the latency of vocalization appears to be clearly the more sensitive measure in differentiating the vocalization performance between skilled and less skilled readers. For the vocalization accuracy measure, the advantage of skilled readers was restricted to low frequency characters, but for the vocalization latency measure, skilled readers were faster than less skilled readers in all conditions. Moreover, multiple comparsions of the means in the latency analysis suggested the possibility that the difference between skilled and less skilled readers might be especially greater for low frequency complex characters than for other classes of characters. In order to confirm this possiblity, correlational and multiple regression analyses were carried out on the vocalization latency means. These analyses were also performed on the log-transformed data of vocalization means and convergent results were obtained (see Appendices G and H). For ease of interpretation, results reported below are based on the mean score analyses.

Pearson product-moment correlations were calculated to compare interrelationships among vocalization latencies of the four classes of character and reading comprehension score. These correlations, as shown in Table 7, indicated that vocalization latencies of low frequency complex characters resulted in the highest correlation with reading comprehension ability ($r = -.61$, $p < .0001$).

To determine the variable that would together best account for reading comprehension, a stepwise multiple regression analysis was performed utilizing vocalization latencies of the four classes of character as predictors and reading comprehension score as the criterion variable. At each step in the analysis, the variable that accounted for the most residual variance in reading comprehension was entered into the regression equation. Stepwise inclusion continued until the improvement in the regression sum of squares at a given step became nonsignificant ($p > .05$). The results are presented in Table 8.

Low frequency complex characters was the first variable entered into the equation, accounting for 38% of the variance in reading comprehension ability [$F(1,44) = 26.44$, $p < .0001$]. After this first step, none of the remaining variables made a significant improvement in prediction. Interpretation of this result, however, must be made with considerable caution. Given the high correlations among variables shown in Table 7, the claim that vocalization speed of low frequency complex characters was the single best predictor of reading ability must be somewhat qualified (Kerlinger, 1979). The results of the correlational and multiple regression analyses, however, were in line with those of the analysis of variance, showing that the difference between skilled and less skilled readers was most evident in naming low frequency complex Chinese characters.

5.3 Experiment 2: Lexical Decision Task

As with Experiment 1, the results of Experiment 2 were first analysed in two separate repeated measured ANOVA's, one for the lexical decision accuracy data and one for the lexical decision latency data. Correlational and multiple regression analyses were later carried out on the latency data.

Table 7

Intercorrelations Among Reading Comprehension Ability and Vocalization Latencies of Four Classes of Characters

(N = 46)

Variables	RC	HS	HC	LS	LC
Reading comprehension ability (RC)	1.00				
High frequency simple character (HS)	-.40	1.00			
High frequency complex character (HC)	-.37	.96	1.00		
Low frequency simple character (LS)	-.47	.73	.73	1.00	
Low frequency complex character (LC)	-.61	.74	.72	.88	1.00

Table 8

Multiple Regression Analysis on Reading Comprehension Utilizing Character Vocalization Latencies (Mean Scores) as Predictors

(N = 46)

Step entered	Variable	Beta weight[a]	Multiple R	R	Increase in R
1	Low frequency complex character	-.91	.61	.38	.38***
2	High frequency complex character	.26			
3	Low frequency simple character	.29			
4	High frequency simple character	-.19			
	1 + 2 + 3 + 4		.63	.40	.02

*** P < .001

a. This column reflects beta weights after all variables were entered.

5.3.1 Lexical decision accuracy

For each subject, accuracy rate of lexical decision was caculated for each of the four classes of character, simple real characters, complex real characters, simple pseudo-characters, and complex pseudo-characters. A 2 (reader ability) x 2 (character type) x 2 (character complexity) analysis of variance with the last two factors repeated was performed on the accuracy data. The means and standard deviations of the accuracy rate values for the subjects by reader ability, character type, and character complexity are given in Table 9. Also, the means of accuracy rate for the two reader groups are graphically presented in Figure 6. Table 10 shows the results of the ANOVA.

A significant main effect for reader ability was obtained [$F(1,44)=4.36$, $p<.05$]. The main effect for reader ability reflected the higher accuracy rate of skilled readers than less skilled readers in making lexical decisions for Chinese characters. The mean accuracy rates for skilled readers and less skilled readers were 92.50% and 89.62% respectively. Overall, skilled readers were 2.88% more accurate than less skilled readers. The accuracy difference between the two groups in lexical decision was moderate but still significant. There was a highly significant main effect for character type [$F(1,44)=32.07$, $p<.0001$], showing that accuracy rate was higher for real characters than for pseudo-characters. Whereas the mean accuracy rate for real characters was 95.60%, it was 86.52% for pseudo-characters. The main effect for character complexity was also significant [$F(1,44)=63.14$, $p<.0001$], reflecting the fewer number of errors for simple characters than for complex characters. For simple characters, the accuracy rate was 94.51%, but for complex characters, it was 87.61%.

Of the interactions, only the character type by character complexity interaction was significant [$F(1,44)=9.47$, $p<.01$]. Multiple comparisons of the means involved in this interaction indicated that, except for the means between simple pseudo and complex real characters, all comparisons were significant ($p<.05$).

Table 9

Means and Standard Deviations[a]
for Lexical Decision Accuracy Rates

Reader ability	Character type	real		pseudo	
	Character complexity	simple	complex	simple	complex
Skilled		98.70% (2.24%)	93.70% (5.48%)	93.26% (8.20%)	84.35% (13.93%)
Less Skilled		96.52% (3.51%)	93.48% (6.11%)	89.57% (7.52%)	78.91% (12.61%)

a. Standard Deviations are presented in parentheses.

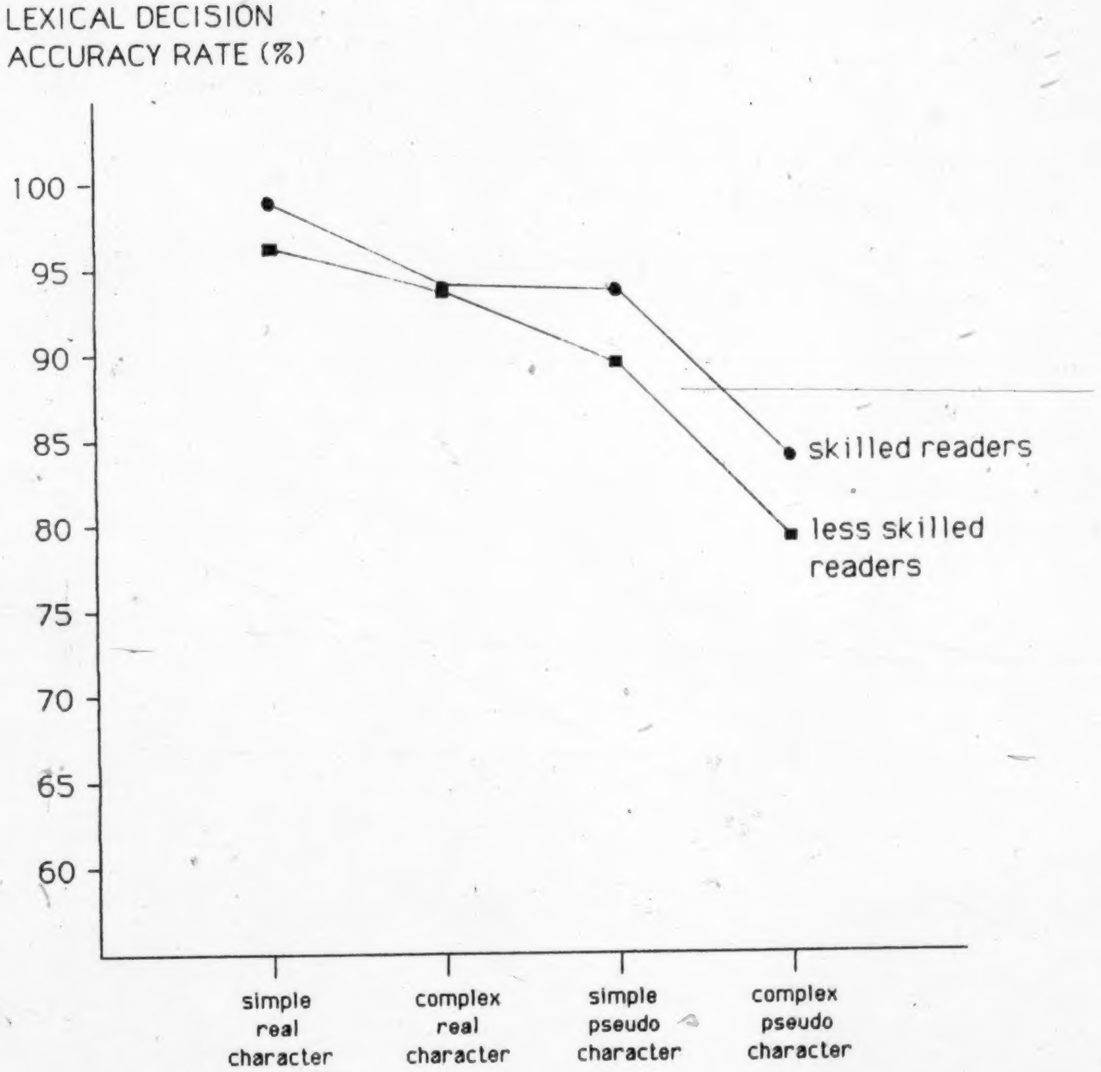

Figure 6. Means of lexical decision on accuracy rate for skilled and less skilled readers as a function of character type and character complexity, collapsed over levels.

Table 10

ANOVA for Lexical Decision Accuracy Data Involving 2 (Reader ability) x 2 (Character type) x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	381.66	4.36*
Error	44	87.62	
Within			
W1 (Character type)	1	3789.27	32.07****
W1 x B1	1	130.57	1.11
Error	44	118.16	
W2 (Character complexity)	1	2191.44	63.14****
W2 x B1	1	0.14	0.001
Error	44	34.71	
W1 x W2	1	381.66	9.47**
W1 x W2 x B1	1	39.27	0.97
Error	44	40.29	

**** P < .0001
** P < .01
* P < .05

The above findings of lexical decision accuracy supported Hypothesis 5 predicting that skilled reader would show a significantly higher accuracy rate of lexical decision than less skilled readers. As shown in Figure 6, skilled readers were more accurate in making lexical decisions for Chinese characters than less skilled readers in all cases.

Since the interaction between reader skill and character type was not significant, Hypothesis 5.1, which stated that the lexical decision accuracy difference between skilled and less skilled readers would be greater for pseudo-characters than for real characters, was not supported.

Similarly, because of the nonsignificant interaction between reader ability and character complexity, Hypothesis 5.2 predicting the greater lexical decision accuracy difference for complex characters than for simple characters between the two reader groups was also not supported.

In short, the findings of lexical decision accuracy demonstrated that skilled readers were more accurate than less skilled readers in making lexical decisions of Chinese characters. Character type and character complexity appeared not to be crucial factors affecting the lexical decision accuracy performance of both skilled and less skilled readers.

5.3.2 Lexical decision latency

As with the vocalization latency data, in the analyses of lexical decision latency performance, only the latencies of correct responses were included. Incorrect responses as well as correct responses that did not stop the timer were eliminated. Across all subjects, the total number of correct responses that did not stop the timer was 8 out of a total of 3680 responses (0.21%). The low incidence of such cases would not constitute a problem affecting the results of the analyses.

Mean lexical decision latencies were caculated for the four classes of character for each subject. As with the vocalization latency data, analyses were performed on subject means as well as on log-transformed data of these means. Again, the results of both analyses provided essentially identical patterns of results. For ease of interpretation, the mean score analyses are the basic data reported below. For the ANOVA results of the log-transformed data of lexical decision latency means, see Appendix I.

As with Experiment 1, the latency data of lexical decision were submitted to a 2 (reader ability) x 2 (character type) x 2 (character complexity) analysis of variance with the last two factors repeated. Table 11 shows the means and standard deviations of the lexical decision latency values of the subjects by reader ability, character type, and character complexity. In Figure 7, the means are graphically presented. The results of the ANOVA for the data are presented in Table 12.

A significant main effect was obtained for reader ability [F(1,44=11.31, p<.01]. The main effect for reader ability reflected the shorter lexical decision latencies for skilled readers than for less skilled readers. While the average lexical decision speed for the skilled reader group was 994 msec, it was 1190 msec for the less skilled reader group. Overall, skilled readers were 196 msec faster than less skilled readers in making lexical decision of Chinese character. It is interesting to note that the magnitude of difference in latency between the two groups in this experiment was very close to that of the first experiment. There was also a significant main effect for character type [F(1,44)=88.10, p<.0001], suggesting the shorter lexical decision latencies for real character (Mean=973 msec) than for pseudo-characters (Mean=1210 msec). The main effect for character complexity was also highly significant [F(1,44)=58.20, p<.0001], indicating that simple characters had shorter lexical decision latencies as compared to complex characters. The mean lexical decision latencies were 1045 msec for simple characters and 1139 msec for complex characters.

Table F1

Means and Standard Deviations[a]
for Lexical Decision Latencies[b] (Msec)

Reader ability	Character type	real		pseudo	
	Character complexity	simple	complex	simple	complex
Skilled		872 (146)	946 (203)	1031 (177)	1126 (221)
Less Skilled		999 (167)	1075 (176)	1277 (291)	1407 (324)

[a] Standard Deviations are presented in parentheses.

[b] Latency values are rounded to the nearest millisecond.

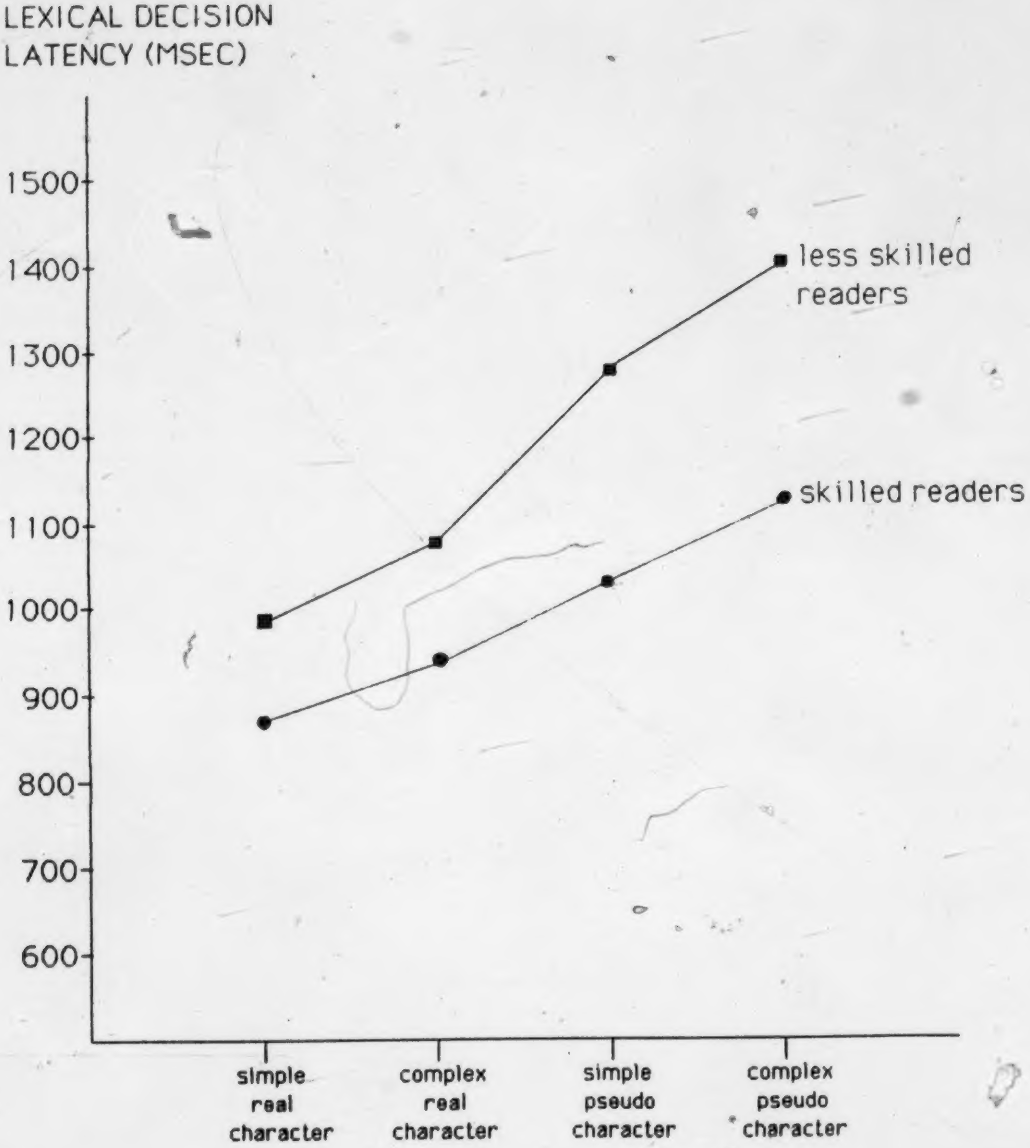

Figure 7. Means of lexical decision latency for skilled and less skilled readers as a function of character type and character complexity, collapsed over levels.

Table 12

ANOVA for Lexical Decision Latency Data (Mean Scores) Involving 2 (Reader ability) x 2 (Character type) x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	1763413.96	11.31**
Error	44	155861.31	
Within			
W1 (Character type)	1	2588278.96	88.10****
W1 x B1	1	213044.14	7.25**
Error	44	29378.51	
W2 (Character complexity)	1	405986.14	58.20****
W2 x B1	1	4028.92	0.58
Error	44	6976.04	
W1 x W2	1	16587.01	4.78*
W1 x W2 x B1	1	3114.40	0.90
Error	44	3470.69	

**** P < .0001
** P < .01
* P < .05

Of the interactions, the reader skill by character type interaction was significant [F(1,44)=7.25, p<.01], and is graphically presented in Figure 8. Using the Tukey (a) procedure, multiple comparisons of the means involved in this interaction were performed. Results revealed that differences between skilled readers and less skilled readers was significant (p<.05) for both real and pseudo-characters. Nevertheless, a smaller difference (128 msec) was observed between the two groups for real characters, whereas a greater difference (264 msec) was obtained between the two groups for pseudo characters.

The character type by character complexity interaction was also significant [F(1,44)=4.78. p<.05]. Multiple comparisons of the means involved in this interaction indicated that all comparisons between these means were significant (p<.05).

The reader skill by character complexity interaction and the three-way interaction were not significant (p>.05).

When log-transformed subjects means were used, all the main effects remained significant. The two previously significant interactions, however, became nonsignificant (See Appendix I). As a trend was still evident in the reader ability by character type interaction (p=0.068), multiple comparisons were further performed on the log-transformed means involved in this interaction using the Tukey (a) method. The pattern of significance of the multiple comparisons remained the same as that in the mean score analysis. In both analyses, skilled readers and less skilled readers showed a greater difference for pseudo-character than for real characters.

The above lexical decision latency analysis supported Hypothesis 6 stating that skilled readers would show overall shorter latencies than less skilled readers in making lexical decisions for Chinese characters. The main effect for reader ability indicated that skilled readers were faster in making lexical decisions of Chinese characters as compared to less skilled readers. Although reader ability interacted with character type, multiple comparisons of the means in this interaction demonstrated that skilled readers

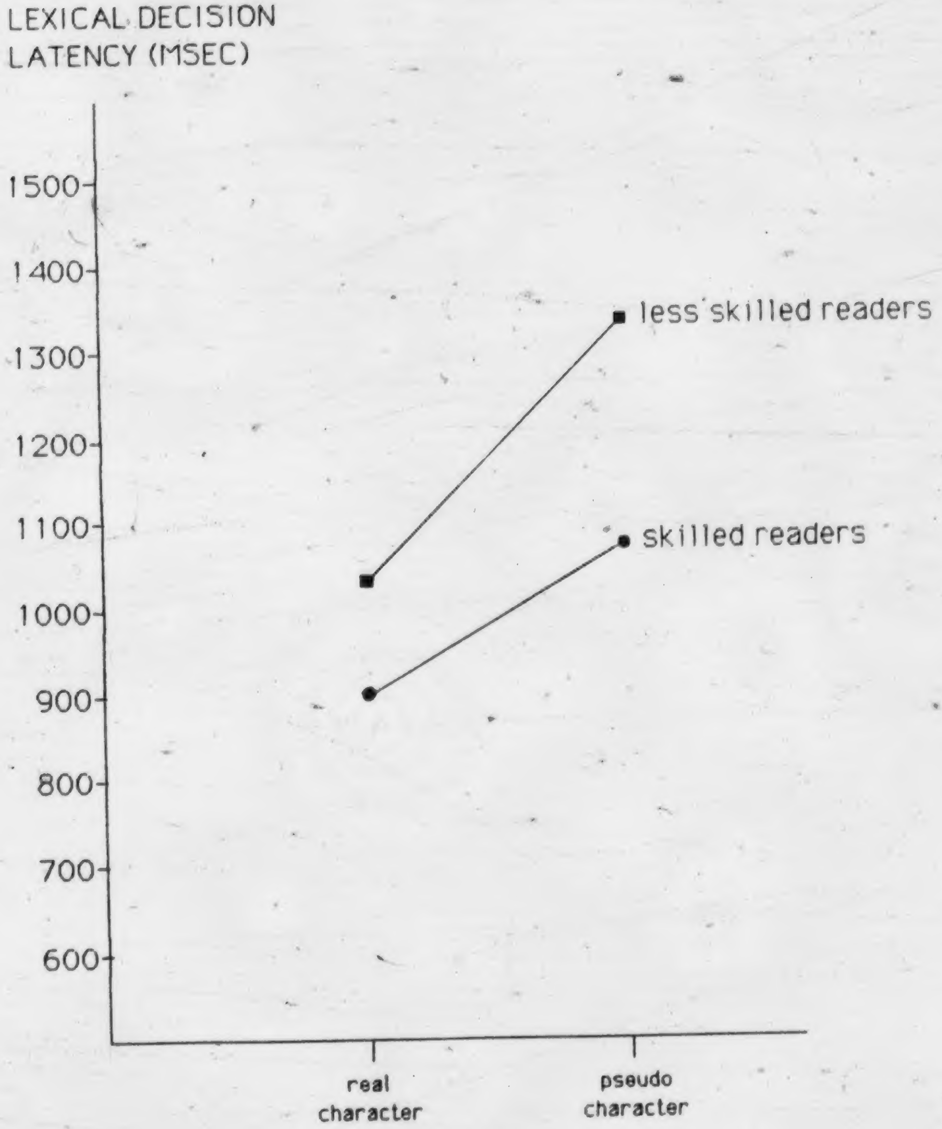

Figure 8. Means of lexical decision latency as a function of character type and reader ability.

were still significantly faster than less skilled readers in making lexical decisions for both real and pseudo characters. Hypothesis 6 was therefore clearly supported.

Hypothesis 6.1 also received support from present results. The two reader groups showed a greater lexical decision latency difference for pseudo-characters than for real characters. As reported earlier, the differences between the two comprehension groups were significant for both levels of character type. The magnitude of difference for pseudo characters, however, was more than twice the difference for real characters. Hypothesis 6.1 was thus supported.

There was no significant interaction between reader skill and character complexity. Thus no support was obtained for Hypothesis 6.2. The two comprehension groups displayed large differences in making lexical decisions for both simple (186 msec) and for complex (205 msec) characters.

The results of Experiment 2 showed that reaction time was again the more sensitive measure in distinguishing the performance of skilled readers from that of less skilled readers. Skilled readers and less skilled readers displayed a moderate difference in lexical decision accuracy but a distinct difference in lexical decision latency, especially for pseudo characters. Consequently, as in Experiment 1, correlational and multiple regression analyses were carried out to further clarify the meaning of the ANOVA results of the lexical decision latency data. As with the vocalization latency data parallel anlayses were also carried out on log-transformed mean scores and similar results were obtained (see Appendices J and K). For ease of interpretation, results reported below are based on the mean score analyses.

Pearson product-moment correlations were caculated to compare interrelationships among the latencies of the four classes of character and reading comprehension score. As presented in Table 13, these correlations indicated that lexical decision latencies of complex pseudo characters resulted in the highest correlation with reading comprehension ability ($r=-.49$, $p<.0001$).

Table 13

Intercorrelations Among Reading Comprehension Ability and Lexical Decision Latencies of Four Classes of Characters

(N = 46)

Variables	RC	SR	CR	SP	CP
Reading comprehension ability (RC)	1.00				
Simple real character (SR)	-.39	1.00			
Complex real character (CR)	-.35	.91	1.00		
Simple pseudo character (SP)	-.47	.75	.78	1.00	
Complex pseudo character (CP)	-.49	.69	.76	.93	1.00

In order to determine the variables that would together best account for reading comprehension, a stepwise multiple regression analysis was carried out using lexical decision latencies of the four classes of character as predictors and reading comprehension score as the criterion variable. The results are given in Table 14. Complex pseudo character was the first and only variable entered into the regression equation, accounting for 24% of the variance in reading comprehension ability [$F(1,44)=13.71$, $p<.001$]. Again, as in experiment 1, interpretation of this result must be cautious in view of the high corrlations among variables as shown in Table 13. Nevertheless, the results of the correlational and multiple regression analyses further confirmed the findings of the analysis of variance showing that the difference between skilled and less skilled readers was most evident in making lexical decisons of complex pseudo Chinese characters.

5.4 General Discussion

Experiment 1 and Experiment 2 provided highly convergent results showing that skilled readers had better performance in identifying Chinese characters, be they required to say the characters aloud or to make lexical judgements of the characters. The superior performance of skilled readers in both accuracy and latency measures reflected the fact that, as comparing to less skilled readers' performance, a speed-accuracy tradeoff did not occur in skilled readers' performance. Moreover, the results of the control task demonstrated evidence against the possibility that the difference between skilled and less skilled readers might be due to a general processing-speed capability. Less skilled readers did not appear to be characterized by a general inefficiency in processing-speed. Rather, they appeared to be less efficient in coding processes specific to verbal materials. Hence, the findings of the present study were in line with the research evidence revealed in the reading literature of English. Word recognition is an important component of skilled reading even in the reading of

Table 14

Multiple Regression Analysis on Reading Comprehension Utilizing Lexical Decision Latencies (Mean scores) of Characters as Predictors

(N = 46)

Step entered	Variable	Beta weight	Multiple R	R	Increase in R
1	Complex pseudo character	-.47	.49	.24	.24***
2	Simple real character	-.35			
3	Complex real character	.36			
4	Simple pseudo character	-.05			
	1 + 2 + 3 + 4		.51	.26	.02

*** P < .001

This column reflects beta weights after all variables were entered.

a logographic script such as Chinese. It was demonstrated in this study that even in the Chinese language, for adults with a relatively high degree of reading proficiency, reading comprehension cannot not be separated from accurate and rapid character recognition.

Conceptually speaking, the observed differences between skilled and less skilled Chinese readers in this study can be explained by the automaticity model put forward by LaBerge and Samuels (1974, Samuels & LaBerge, 1983) and be examined in terms of the verbal efficiency theory proposed by Perfetti and Lesgold (1977; Perfetti, 1985a,b). As reviewed in Chapter 2, the automaticity model, based on the premise of the limited capacity of attention, proposes that lower-level word recognition must be processed automatically and rapidly to make attention available to accomplish higher-level comprehension processes. Similarly, the verbal efficiency theory, stressing the limited capacity of working memory, suggests that efficient decoding processes can free working memory capacity for comprehension processes. Analysing the findings of the present study in view of these models, it appears that less skilled readers, due to their inefficient character recognition skill, were unable to make their attention and working memory resources more available for comprehension processes and therefore displayed poorer comprehension performance. In other words, the skilled reader of Chinese, just like the skilled reader of English, is the one who identifies words automatically and rapidly and thus has more cognitive resources to accomplish better comprehension performance.

Comparing the results of the accuracy data and of the latency data in both experiments, while the major patterns of findings remained the same, slight differences were also obtained in the two measures (see Figure 9 for comparisons of the results of the two experiments). It appears that accuracy had only partial success in differentiating skilled readers from less skilled readers. As illustrated in Figure 9, skilled and less skilled readers showed little difference for high frequency characters

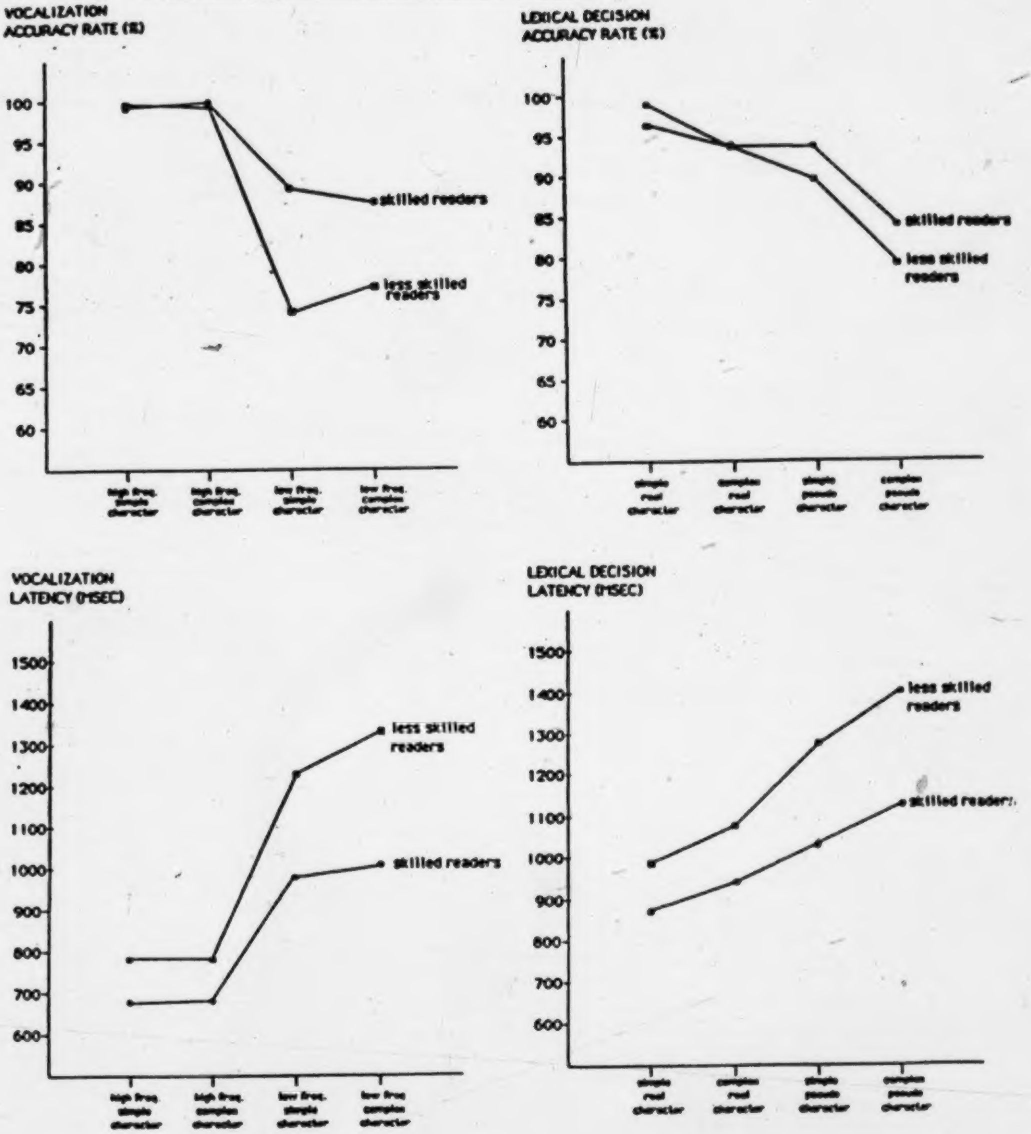

Figure 9. Comparison of the results of the two experiments.

and for real characters in terms of accuracy. By contrast, the differences between skilled and less skilled readers were evident in all cases when the latency measure was used. In other words, in both experiments latency was the more sensitive measure in distinguishing skilled from less skilled readers. How can the discrepancy between the accuracy and latency results be explained?

First, as pointed out by Leong and his associates (1985), it is possible that accuracy and latency may not measure the same perceptual processes. Leong et al. (1985) brought forward the theoretical analysis offered by Smith and Spoehr (1974) and stated:

> Under "data-limited" tachistoscopic viewing conditions with brief exposure times, response accuracy seems to reflect early perceptual interference between target and noise and the limited time for extraction of input information, whereas reaction time might be more sensitive to later decision processes involved in response interpretation (p.141).

Accordingly, the discrepancy between the accuracy and latency results obtained in this study may point to the possibility that different perceptual processes of character recognition are involved. Further research, however, is needed to determine specific similarities and differences as reflected in these two measures.

Still another explanation can be drawn from the work of Ehri and Wilce (1979, 1983). The researchers have developed a model concerning the development of word recognition skill based on the LaBerge and Samuals automaticity model. The attainment of word recognition skill is analysed into three subsequent phases: accuracy, automaticity, and speed. Applying this model to the results of the present study, some interesting hypotheses can be generated. It is possible that both skilled and less skilled readers had reached the accuracy stage of word recognition for high frequency characters in Experiment 1 and for real characters in Experiment 2. Consequently, little performance differences in these areas were obeserved. However, whereas skilled readers had attained automatic and rapid word recognition skill beyond the accuracy phase, less skilled readers had not gone beyond the accuracy stage. As a result, differences between the two comprehension groups were distinct in all conditions using the latency measure. While such speculations are reasonable, verification of their validity is beyond the scope of the present study. Further studies may be conducted to explore the issue.

Integrating the results of the overall study, it seems that it is low frequency characters and pseudo characters that best discriminate the performance of skilled readers from that of less skilled readers. How can one account for such effects? Following the work of Perfetti and his associates (e.g. Hogaboam & Perfetti, 1978; Perfetti & Hogaboam, 1975), Stanovich (1981), and Haines and Leong (1983), it is proposed that such effects can be attributed to the extent of verbal knowledge that skilled and less skilled readers possess. For skilled readers, because of their abundant verbal knowledge, there is a lot of redundant information inherent in a printed character and this redundant information makes them less vulnerable to the effects of frequency, type, and complexity of the printed character. On the contrary, for less skilled readers, the lack of verbal knowledge prevents them from the efficient use of available information to make lexical access. The role of linguistic awareness suggested by Leong (1978, Leong & Sheh, 1982) and Tzeng and Hung (1981) therefore may play an important role in the development of reading fluency even in the reading of the logographic script.

Finally, comparing the effects of character frequency, character type and character complexity, character complexity appears to be the less potent variable affecting the performance of both skilled and less skilled readers. One explanation of this result is that in this study the classification of simple and complex characters in terms of number of strokes was not extreme enough to demonstrate a strong effect on character recognition. As noted before, the average number of strokes of complex characters in this study was 13.5 and characters of more than 16 strokes were not selected. It is possible than when more complex characters (say characters of more than 20 strokes) are included, a stronger effect of character complexity may be obtained. Still, another alternative explanation should be considered. It is possible that the complexity of a character does not rely solely on the number of strokes. As Leong (1977) has pointed out, other than the number of strokes, factors such as the internal structure and balance of the character, the confusability of graphemes with similar configurations, and the acoustic confusability of homophones should be taken into consideration when defining the complexity of a character.

What implications and suggestions, then, can be derived from the findings of this study? In the following chapter, a review of the overall study will be presented, with implications and suggestions for future research and reading practice discussed.

6. CONCLUSIONS

6.1 Review of the Study

The purpose of the present study was to attempt to answer the question: What is the relationship between rapid, automatic recognition of context-free Chinese character recognition and reading comprehension ability in Chinese adult readers? By presenting an extensive review of the reading literature in English, it was deomonstrated that most theoretical models of reading postulate a direct relationship between efficient word recognition and reading comprehension ability. Such a postulation has gained support from a variety of studies using different research paradigms. Studies of eye movement patterns, studies of word recognition automaticity, studies of word recognition speed, and studies of word recognition in context have all pointed to the repeated finding that accurate, automatic, and rapid context-free word recognition is a key factor disinguishing skilled and less skilled readers from beginning years up to adulthood. In contrast, a search into the reading research of Chinese reveals that the relationship between word recogntion and reading ability has rarely been explored. Although it is reasonable to assume that different writing systems may entail different relationships between word reocgnition and reading comprehension fluency, careful analysis of Chinese and English as writing systems discloses the isomorphy of Chinese with English. Empirical evidence has also shown that similar fundamental operations are implicated in processing Chinese and English. Along this line of reasoning, it logically follows that there might also be a strong relationship between word recognition and reading comprehension ability in Chinese readers.

On the basis of the above analyses, this study attempted to answer the question by conducting two experiments and a control task. Experiment 1 employed a vocalization task whereas in Experiment 2 a lexical decision task was used. Matching of dot patterns was utilized as a control task. The usefulness of these tasks is well documented in reading research of English. The results from these experiments were in line with those of English reading studies. As in the case of reading English, it was demonstrated in this study that decoding and lexical access speed of Chinese characters distinguish skilled and less skilled Chinese readers. Moreover, low frequency characters and pseudo characters turn out to be the more potent variables differentiating the performance of skilled and less skilled readers.

Hence, in general, the aim of this study, in terms of furthering our knowledge about the relationship between word recognition and reading ability through an investigation of the performance of Chinese readers, has seemingly been met.

6.2 Implications for Future Research and Reading Instruction

Several implications and suggestions can be derived from the results of the present study.

First, since this study only dealt with Chinese adult readers, it would be of interest to extend the present investigation to younger reader in an attempt to gain further insights into the nature of individual differences in reading in Chinese children.

Second, speaking in terms of stimulus selection, it was shown in this study that low frequency characters and pseudo characters are the two more potent variables differentiating the performance of skilled and less skilled readers. As a result, it is suggested that these two variables be further investigated in future research. On the other hand, due to only partial success with the manipulation of the variable character complexity in this study, future researchers who are interested in examining the effect of character complexity on character recognition are advised to take other factors such as the structure and balance as well as the semantic-phonetic components of the character into consideration.

Third, the demonstration of the strong relationship between word recognition and reading ability in this study is confined to visual recognition of single characters and its relationship to reading comprehension ability. Since most Chinese words are two-character words, future research should further explore the issue by extending the research paradigm to two-character words. It would also be interesting to investigate how various contexts affect character and word recognition in Chinese readers.

Although more research is needed before any specific implications for reading instruction in Chinese should be made, one general implication can be derived from present results is that, since word recognition is highly related to reading comprehension, children should be taught to master word recognition skill. Specifically, as the results of this study have shown, accuracy of word recognition is moderately related to reading ability while speed of word recognition is highly related to reading ability. It is thus suggested that automatic and rapid word recognition is a useful instructional goal beyond accuracy.

It should be noted that, however, the above suggestion does not imply that merely speeded practice of word recognition naturally leads to better reading comprehension. Research evidence (e.g., Fleisher, Jenkins, & Pany, 1979) has shown that merely training a student to say words quickly does not necessarily result in better comprehension. Moreover, as pointed out earlier, it is likely that the deficient word recognition performance of less skilled readers might be due to their lack of verbal knowledge. Linguistic awareness, therefore, plays an important role in the development of reading skill. In this context, Perfetti (1985b) nicely describes the interrelationship between verbal knowledge and reading practice:

> ... lexical access is a fairly complex business and that children who are not good at it typically have insufficient knowledge concerning orthography or related components of lexical knowledge. This leads to a different perspective: Children need to acquire a rich word representation system, including the decoding principles. Practice will increase efficiency given adequate knowledge, but speed of word processing itself is a by-product of the acquisition of lexical knowledge and of practice at using this knowledge. Thus speed of processing reflects knowledge and practice, and lack of speed reflects lack of knowledge or lack of practice (p.235).

Following Perfetti's analysis, it is suggested that both speed and knowledge of decoding principles are objectives of reading instruction. Again, this suggestion does not imply that other comprehension instructions are not useful. Indeed, the interactive nature of the reading process clearly assumes the interdependence of word recognition and reading comprehension. All in all, what is suggested here is that efficient word recognition including the learning of decoding principles should be objectives of reading instruction. This does not deny the possible contributions of other reading instructions.

In conclusion, by investigating the relationship between word recognition and reading ability through the performance of a group of Chinese adult readers, the present study provided some insights into the nature of reading as a universal linguistic acitvity. Given the wide-spread use and the unique characteristics of the Chinese language, it is an extremely fertile area for the study of human linguistic information processing. Further studies of reading in Chinese will definitely provide some more fruitful results contributing to our understanding of the process of reading.

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APPENDICES

Appendix A

Comprehension Sample 1

陶侃在廣州無事，輒朝運百甓於齋外，暮運於齋內。人問其故，答曰：「吾方致力中原，過爾優逸，恐不堪事，故自勞耳。」

太寧三年五月，以陶侃爲征西大將軍、都督荊湘雍梁四州諸軍事、荊州刺史，荊州士女相慶。

侃性聰敏恭勤，終日斂膝危坐，軍府衆事，檢攝無遺，未嘗少閑。常語人曰：「大禹聖人，乃惜寸陰，至於衆人，當惜分陰。豈可但逸遊荒醉，生無益於時，死無聞於後，是自棄也！」

諸參佐或以談戲廢事，命取其酒器、蒱博之具，悉投之於江，將吏則加鞭扑，曰：「樗蒱者，牧猪奴戲耳！老莊浮華，非先王之法言，不益實用。君子當正其威儀，何有蓬頭、跣足，自謂宏達邪！」

有奉饋者，必問其所由，若力作所致，雖微必喜，慰賜三倍；若非理得之，則切厲訶辱，還其所饋。

嘗出遊，見人持一把未熟稻，侃問：「用此何爲？」人云：「行道所見，聊取之耳。」侃大怒曰：「汝既不佃，而戲賊人稻！」執而鞭之。是以百姓勤於農作，家給人足。

13. 陶侃爲甚麼早晚都搬運磚塊？

(1) 他想鍛鍊身體。
(2) 他凡事親力親爲。
(3) 他無事可做，藉此消閑。
(4) 他要磨鍊意志。
(5) 他爲建設中原而貯備物資。

A 只有(1) (3)
B 只有(1) (4)
C 只有(2) (3)
D 只有(1) (2) (5)
E 只有(2) (4) (5)

14. 下列哪幾項是陶侃疾惡下屬去做的事？

(1) 談論戲劇。
(2) 賭博。
(3) 跟養猪的人嬉戲。
(4) 飲酒作樂。
(5) 研讀老莊著作。

A 只有(2) (4)
B 只有(1) (2) (3)
C 只有(2) (3) (5)
D 只有(1) (3) (4) (5)
E 只有(2) (3) (4) (5)

15. 陶侃爲甚麼懲罰那個拿着稻穗的人？

(1) 因爲那人存心偷取禾稻。
(2) 因爲那人把拔稻的事當作兒戲。
(3) 因爲那人所拔下的稻子還未成熟。
(4) 因爲那人不肯耕種。
(5) 因爲那人損毀他人的農作物。

A 只有(1)
B 只有(1) (4)
C 只有(2) (3)
D 只有(2) (5)
E 只有(3) (5)

16. 陶侃對別人的饋贈，持怎樣的態度？

A 凡有饋贈，必回謝三倍。
B 只考慮接受微薄的禮物。
C 只收取勞苦的人送來的禮物。
D 將禮物全部退還，並斥責送禮的人。
E 要看禮物是否憑那人的勞力而得來的。

Complehension Sample 2

五月三日，像一匹疲於奔走的馬找到一個驛站，一隻倦於飛行的鳥獲得一枝棲息，我終於覓到這一角僻靜的處所，如今，離塵囂已是很遠很遠了。除了自己，我是空着手來的，沒有攜帶一支筆，一本書，甚至任何印刷有字跡、與現世有關聯的紙片，我拋下一切世俗的負載，如同生下不久送去上帝面前受洗的嬰兒，把自己投呈在大自然面前。

噢，我不是逃避生活，世上儘管有躲避烈日的蓬帳，有躲避風雨的場屋，但沒有躲避生活的所在，而在生活的搏鬪中，我並不卑怯，我也不是脫離現實，生命有如植物，而現實便是土地，沒有植物能不生根於土地而生存。現實儘管不美且令人窒悶，我也還能面對它不屈，更不是爲感情上有甚麼糾葛，儘管當年輕時也曾如狂瀾激流，如今也只似那止水，蘊伏於靈魂深處，微波不揚，我所以覓一角僻靜的處所，只爲我病了，需要養息。

病了，是的，但不是軀體上的病，我畢生與病魔抗爭，從不懼怕。而此刻，病了的卻是我的心靈，它感到無比的疲倦，對一切厭煩——不再憧憬，停止幻想，更缺希望，彷彿被煙煤淤塞的燈盞，不再發出光和熱。

高明的醫生曾從死亡邊緣救回多少病重的人，但可有治這心靈凍結的醫生？

神秘的特效藥曾治愈多少絕症，但可有治這心靈萎頓的藥品？

噢，沒有，沒有聽說過。

茫然中，我無意記起了一個詩人的話……只要你認識了自然，在這世界上寂寞時便不寂寞，窘困時不窘困，苦惱時有安慰，挫折時有鼓勵，軟弱時有督責，迷失時有南鍼……

於是，我暫時拋棄一切所有，悄悄地來了這裏

37. 作者要覓得一角僻靜的處所，因爲
- A 他心靈上感到疲倦
- B 他不滿現實
- C 他想做個隱士
- D 他的情緒不安
- E 他的軀體有病

38. 作者對現實的看法是：
- A 現實能激發雄心
- B 現實是應該逃避的
- C 現實是冷酷無情的
- D 現實是醜惡而悶人的
- E 現實令人喪失鬥志

39. 當作者的心靈病了的時候，他的心情是
- A 死寂的。
- B 苦悶的。
- C 激動的。
- D 矛盾的。
- E 愉快的。

40. 作者認爲治療心靈的病最佳的方法是：
- A 冷靜地以理智處事
- B 勇敢地接受現實的挑戰
- C 去看高明的醫生
- D 在靜中經常自我檢討
- E 拋卻俗務，重返自然

Appendix B

Comprehension Sample 1

When Tao Hon retired and live in Canton, he transported 100 bricks out of his study room every morning, and transported them back there again in the evening. People wondered and asked him. He said, "The government is undertaking the task of recovering its territory. If our life is too comfortable, I doubt if the goal will be achieved. Therefore, I want myself be laborious."

Later, Tao was named commander of the west expedition, in charge of the military affairs of four great districts. Officials and ordinary citizens of these districts were just happy to learn that.

Tao was clever and hard working; he was always at his desk. He oversaw even every minor business of his army and had little free time. He always said, "Emperor Yu was a saga, but he dared not waste a minute; we are ordinary people, therefore, we should not waste a second. We should not indulge ourselves in playing and drinking. If a person does not do something for his society, he will not be remembered when he dies. It is a disgrace."

Whenever Tao found his subordinates in a party, he ordered to throw all the drinking and game equipment into the river, and had the subordinates severly beaten. He said, "Games are for lowly people. Taoism (philosophy of Lao Tze) is not a saga's teaching but empty talk. It does not lead to a good life. As gentlemen, you must lead a serious life. Therefore, you must not be unrestrained in your own manner."

Whenever somebody presented him a gift, Tao must ask where it was from. If it was made by that person, Tao would be happy and accept it. In return he would give the person a gift of three times the worth. If the person could not give a satisified reason explaining how the gift was from, Tao would reprimand him and not accept it.

One day, Tao was on a tour around the county. He saw a person holding a bundle of green rice plant. Tao asked him, "What is it for?" The person said, " I found it on my way. So I took it for play." Tao was furious and said, "You are not a farmer, but you waste other people's rice plant." Tao beat that person with it. Consequently, people under his government worked hard in argicultural production. Everbody was well fed.

Answer the following questions:

13. Why did Tao Hon transported the bricks day and night?
    (1) He wanted to strengthen his body.
    (2) He did everything himself.
    (3) He wanted to use up his leisure time, but he did not have other things to do.
    (4) He wanted to strengthen his mind.
    (5) He collected materials for the country's development.
        A. Only (1) (3)
        B. Only (1) (4)
        C. Only (2) (3)
        D. Only (1) (2) (5)
        E. Only (2) (4) (5)

14. In the following, what were the things Tao Hon forbid his subordinates to do?
    (1) Discuss opera.
    (2) Gamble.
    (3) Party with herdsmen.
    (4) Party and drink wine.
    (5) Discuss works of Lao Tze and Chuang Tze (Taoism).

A. Only (2) (4)
B. Only (1) (2) (3)
C. Only (2) (3) (5)
D. Only (1) (3) (4) (5)
E. Only (2) (3) (4) (5)

15. Why did Tao punish the person who was holding a bundle ofgreen rice plant in his hand?
(1) Because that person stole it.
(2) Because that person thought it was fun to pull out rice plant from the field.
(3) Because the rice plant that person pulled out was not grown yet.
(4) Because that person was unwilling to do farm work.
(5) Because that perosn damaged the produce of others.
A. Only (1)
B. Only (1) (4)
C. Only (2) (3)
D. Only (2) (5)
E. Only (3) (5)

16. What was Tao Hon's attitude towards people who presented him a gift?
A. Whenever he was presented a gift, he returned that person a gift three times the value.
B. Tao would only accept small gifts.
C. Tao would only accept gifts presented by laborers.
D. Tao would not accept any gift. Instead he would reprimand the sender.
E. It depended on if the gift was made by the person himself.

Comprehension Sample 2

On the third day of May, like an ever-galloping horse which arrived at a stable, or a tired bird which flew to a branch, I finally settled down at a quiet place. Now, I am far far away from town. I came here with empty hands, without a pen, a book, nor a printed page that has anything associated with the present. I am clear of any responsiblity in this world, just like a new born baby which is to be baptized in front of God and to be presented to nature.

I am not escaping from life. There are shelters of the hot sun and the storm, but there is no refuge of life. I am not worried about the struggles in my life, neither am I turning myself away from society. To live is like to grow a plant, reality is the soil. No plants will grow if they are not grown in the soil.

No matter how unfascinating and suffocating reality is, I still can stand it, not for emotional reasons. Although in younger days, I was as aggressive as a torrent, now I am as calm as the unrunning water. All my feelings reside deep down in my mind, and are not agitated. I retreat to this quiet place because I am ill, in need of some rest.

Being ill? Yes, but not physically. I have struggled with illness in my whole life. I have never backed down. Now, it is my mind that is ill. It is too tired that it does not regard a thing inspirational, idealistic, imaginative, or hopeful. It is like a coal-oil light that, being suffocated by it own deposit, gives out not light and heat.

A clever doctor rescues lives. Is there a clever doctor who can cure an unaffective mind?

Wonderful medicines cure hopeless illness. Is there a medicine for a withering mind?

No. I have not heard of it. Suddenly, a poet came to my bewildered mind. He said ... if you understand nature, you will not feel lonely when the world is unactive. You will not feel bored when it is void. You will have consolation when you are fustrated, words of encouragement when you experience setbacks, support when you are tired, and guidance when you are at a loss.

Thus, I give up everything, quietly come to this place.

Answer the following questions:

37. The writer wants a quiet place because
    A. His mind is exhausted.
    B. He is cynical.
    C. He wants to be a hermit.
    D. He is emotional.
    E. He is physically sick.

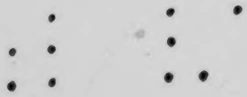
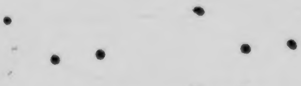
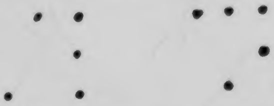
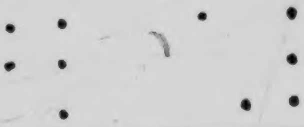
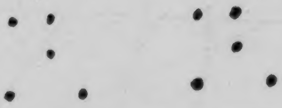
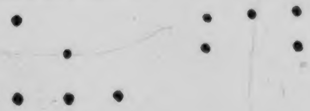
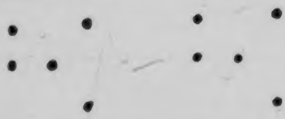
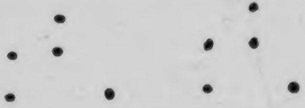
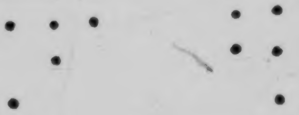
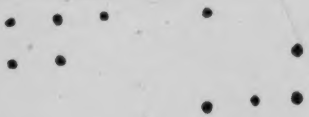
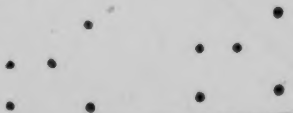
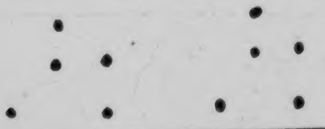
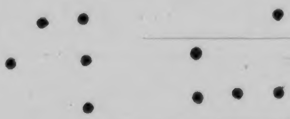
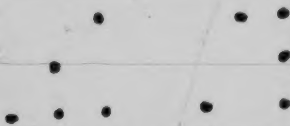
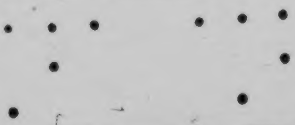
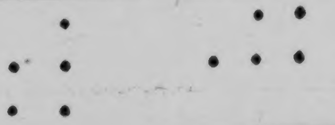
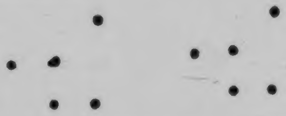
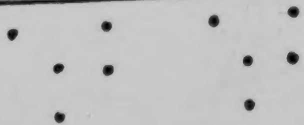
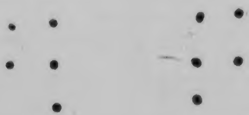
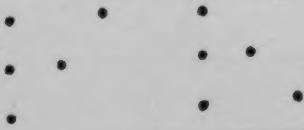
38. The writer's opinion of reality is that
    A. Reality inspires ambition.
    B. One should escape from reality.
    C. Reality is cruel and merciless.
    D. Reality is ugly and boring.
    E. Reality smoothes a person's ambition.

39. When the writer is mentally exhausted, he is
    A. Absolutely quiet.
    B. Extremely bored.
    C. Passionate
    D. Contradictory.
    E. Happy.

40. He believes the best cure for himself is
    - A. Being calm and rational.
    - B. Being brave to accept any challenge.
    - C. To see a good doctor.
    - D. To frequently reflect what he did.
    - E. To be detached from society, and to return to nature.

Appendix C

Appendix C: stimuli for matching dot patterns

item	pattern	item	pattern
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

Appendix D

Appendix D: stimuli for vocalization task

class	5 strokes freq grade	6 strokes freq grade	7 strokes freq grade	8 strokes freq grade	9 strokes freq grade	remarks
1. high frequency, simple characters (20 items)	叫 1101 1	地 4604 1	作 3315 1	到 5548 1	活 1592 3	frequency range 925-5548 mean frequency count 2070.35 stroke range: 5-9 average stroke: 7.4
		她 3272 1	但 2146 2	法 2312 1	計 933 2	
		合 1211 2	你 2017 1	物 2292 1	苦 950 2	
			位 1802 1	定 2264 1		
			利 1196 2	明 1327 1		
			形 1114 2	空 946 1		
				放 925 2		
	5 strokes freq grade	6 strokes freq grade	7 strokes freq grade	8 strokes freq grade	9 strokes freq grade	
2. low frequency, simple characters (20 items)	汁 20 2	帆 28 2	咆 30 5	刺 23 2	苟 18 5	frequency range 4-30 mean frequency count: 15.9 stroke range: 5-9 average stroke 7.35
		奸 24 4	抒 25 5	怯 22 5	咳 8 6	
		匠 16 3	抄 20 3	泣 19 6	紉 4 6	
		吝 6 5	伶 13 5	玫 15 5		
			皂 4 5	怡 8 5		
				帕 8 3		
				肪 7 6		
	12 strokes freq grade	13 strokes freq grade	14 strokes freq grade	15 strokes freq grade	16 strokes freq grade	
3. high frequency, complex characters (20 items)	都 3461 1	會 4815 1	說 5640 1	樣 2295 1	學 3667 1	frequency range: 903-5640 mean frequency count: 2268.35 stroke range 12-16 average stroke 13.65
	開 1916 1	道 3394 1	種 3349 1	論 903 3	戰 960 3	
		當 2503 1	麼 1413 1			
		想 2283 1	像 1260 1			
		過 1549 1	稱 1049 3			
		新 1380 1				
		電 1085 2				
		運 1028 2				
		路 917 1				
	12 strokes freq grade	13 strokes freq grade	14 strokes freq grade	15 strokes freq grade	16 strokes freq grade	
4. low frequency, complex characters (20 items)	喘 29 5	潘 24 5	竭 30	賜 27 6	憾 26 6	frequency range: 3-30 mean frequency count: 15.2 stroke range 12-16 average stroke 13.15
	欽 16 4	碑 14 5	誦 23	熨 3 3	糕 18 1	
	婿 3 6	頌 10 5	鄙 17			
		畸 7 5	漆 16			
		痰 6 3	滯 13			
			駁 7			
			嫉 9			
			綢 6			

overall mean frequency count of high frequency words: 2169.35

overall mean frequency count of low frequency words: 15.55

Appendix E

Appendix E : stimuli for lexical decision task

class	5 strokes freq. grade	6 strokes freq. grade	7 strokes freq. grade	8 strokes freq. grad.	9 strokes freq. grade	remarks
1 simple real characters	加 1834 1 扒 7 5	好 3400 1 妄 24 5	那 4549 1 沒 2326 1 每 1291 1 汪 29 2 吶 10 5 刪 10 5 吠 2 2	和 5272 1 所 4210 2 知 2053 1 近 946 1 帖 20 4 孤 10 4 斧 7 6	政 1552 3 炮 10 4	frequency range: 2 - 5272 mean frequency count: 1378.35 stroke range: 5 - 9 average stroke: 7.25
	5 strokes	6 strokes	7 strokes	8 strokes	9 strokes	
2. simple pseudo characters	仁口 忄八	子女 亡子	形 炈 笔 火王 土内 册卜 土犬	礻口 阝丰 矛口 阝斤 彳占 阝瓜 父丰	正欠 怉	stroke range: 5 - 9 average stroke: 7.25
	12 strokes freq. grade	13 strokes freq. grade	14 strokes freq. grade	15 strokes freq. grade	16 strokes freq. grade	
3. complex real characters	就 5015 1 給 955 1 絮 9 5	經 2590 2 意 1967 2 解 995 3 話 914 1 罩 30 6 頒 23 6 塌 14 5 詼 3 6	對 3380 1 實 1748 1 綴 22 4 慷 9 5 寥 5 6	數 1410 1 澄 19 5 魄 12 5	機 1198 1	frequency range: 3 - 3380 mean frequency count: 1015.9 stroke range: 12 - 16 average stroke: 13.55
	12 strokes	13 strokes	14 strokes	15 strokes	16 strokes	
4. complex pseudo characters	糸彡 拾 如木	米巠 音灬 角羊 足舌 ⺮早 分頁 口日羽 足灰	豈彡 广貫 米叕 犭康 廖	婁戈 憕 塊	扌幾	stroke range: 12 - 16 average stroke: 13.55

reall character mean frequency: 1197.125

Appendix F

Table of ANOVA for Vocalization
Latency Data (Log-transformed Mean Scores)
Involving 2 (Reader ability) x 2 (Character frequency)
x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	1.69	16.69***
Error	44	0.10	
Within			
W1 (Character frequency)	1	8.37	502.97****
W1 x B1	1	0.16	9.50**
Error	44	0.02	
W2 (Character complexity)	1	0.04	15.70***
W2 x B1	1	.64605D-2	2.38
Error	44	.27099D-2	
W1 x W2	1	0.03	10.39**
W1 x W2 x B1	1	.96241D-2	3.21
Error	44	.29940D-2	

**** P < .0001
*** P < .001
** P < .01

Appendix G

Table of ANOVA for Lexical
Decision Latency Data (Log-transformed Mean Scores)
Involving 2 (Reader ability) x 2 (Character type)
x 2 (Character complexity)

(N = 46)

Source	DF	MS	F
Between			
B1 (Reader ability)	1	1.41	11.44**
Error	44	0.12	
Within			
W1 (Character type)	1	2.01	106.88****
W1 x B1	1	0.07	3.51
Error	44	0.02	
W2 (Character complexity)	1	0.31	66.81***
W2 x B1	1	.55722D-2	0.12
Error	44	.46085D-2	
W1 x W2	1	.36124D-2	1.41
W1 x W2 x B1	1	.36189D-2	0.14
Error	44	.2560D-2	

**** P < .0001
** P < .01

Appendix H

Table of Intercorrelations among Reading Comprehension and Vocalization Latencies (Log-transformed Mean Scores) of Four Classes of Characters

(N = 46)

Variable	RC	HS	HC	LS	LC
Reading comprehension ability (RC)	1.00				
High frequency simple character (HS)	-.41	1.00			
High frequency complex character (HC)	-.38	.97	1.00		
Low frequency simple character (LS)	-.49	.78	.76	1.00	
Low frequency complex character (LC)	-.61	.74	.72	.91	1.00

Appendix I

Table of Multiple Regression Analysis
on Reading Comprehension Utilizing Character
Vocalization Latencies (Log-transformed Mean Scores)
as Predictors

(N = 46)

Step entered	Variable	Beta weight[a]	Multiple R	R	Increase in R
1	Low frequency complex character	-.94	.61	.37	.37***
2	High frequency complex character	.20			
3	Low frequency simple character	.34			
4	High frequency simple character	-.16			
	1 + 2 + 3 + 4		.63	.40	.03

*** $P < .001$

a. This column reflects beta weights after all variables were entered.

Appendix J

Table of Intercorrelations among Reading Comprehension and Lexical Decision Latencies (Log-transformed Mean Scores) of Four Classes of Characters

(N = 46)

Variable	RC	SR	CR	SP	CP
Reading comprehension ability (RC)	1.00				
Simple real character (SR)	-.40	1.00			
Complex real character (CR)	-.37	.92	1.00		
Simple pseudo character (SP)	-.47	.75	.78	1.00	
Complex pseudo character (CP)	-.49	.71	.78	.93	1.00

Appendix K

Table of Multiple Regression Analysis on Reading Comprehension Utilizing Lexical Decision Latencies (Log-transformed Mean scores) of Characters as Predictors

(N = 46)

Step entered	Variable	Beta weight[a]	Multiple R	R^2	Increase in R^2
1	Complex pseudo character	-.50	.49	.24	.24***
2	Simple real character	-.39			
3	Simple pseudo character	-.03			
4	Complex real character	.40			
	1 + 2 + 3 + 4		.51	.26	.02

*** P < .001

[a] This column reflects beta weights after all variables were entered.